14:24:59 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 12/04/95

Active

Project #: E-24-X16 Cost share #: Rev #: 13
Center # : 10/24-6-R7804-0A0 Center shr #: OCA file #:
Work type : RES
Contract#: AGREEMENT SIGNED 3/22/93 Mod #: ADMIN Document : AGR
Prime #: Contract entity: GTRC

Subprojects ? : N CFDA: NA
Main project #: PE #: NA

Project unit: ISYE Unit code: 02.010.124
Project director(s):
KIRLIK A ISYE (404)894-4055

Sponsor/division names: AT&T GLOBAL SOLUTIONS / DULUTH, GA
Sponsor/division codes: 250 / 062

Award period: 930101 to 951201 (performance) 951201 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	272,060.50
Funded	0.00	272,060.50
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: USABILITY ANALYSIS LABORATORY I

PROJECT ADMINISTRATION DATA

OCA contact: Robert D. Simpkins 894-4820

Sponsor technical contact

MARK HOFFMAN
(404)623-7463

NCR CORPORATION
ENGINEERING & MANUFACTURING ATLANTA
2651 SATELLITE BOULEVARD
DULUTH, GA 30136

Sponsor issuing office

MARK HOFFMAN
(404)623-7463

NCR CORPORATION
ENGINEERING & MANUFACTURING ATLANTA
2651 SATELLITE BOULEVARD
DULUTH, GA 30136

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A N/A supplemental sheet
Equipment title vests with: Sponsor X GIT

Administrative comments -
ADMINISTRATIVE MOD ISSUED TO MOVE FUNDS FROM CAPITAL OUTLAY TO EQUIPMENT (TITLE TO SPONSOR). SPONSOR WILL PICK UP ALL EQUIPMENT PURCHASED.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 01/23/96

Project No. E-24-X16 Center No. 10/24-6-R7804-0A0

Project Director KIRLIK A School/Lab ISYE

Sponsor AT&T GLOBAL SOLUTIONS/DULUTH, GA

Contract/Grant No. AGREEMENT SIGNED 3/22/93 Contract Entity GTRC

Prime Contract No.

Title USABILITY ANALYSIS LABORATORY I

Effective Completion Date 951201 (Performance) 951201 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

E-24-X16
/

Usability Analysis Laboratory II

ANNUAL REPORT

ATT Global Information Solutions
2651 Satellite Boulevard
Duluth, GA 30136

ATTN: Mr. Mark Hoffman

from:

Alex Kirlik
Center for Human-Machine Systems Research
School of Industrial and Systems Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0205

For the period 3/1/94 - 2/28/95
Georgia Tech Project No. E24-X16

Contents

Video Analysis Laboratory

Other Activities

Projects during 1994

Sears

The purpose of this test was to evaluate Sears retail workstation design. The tapes recorded transactions by cashiers using the CompuAdd terminals in the Lady's Apparel and Hardware sections of Sears' Newark, California store.

Office Depot

The purpose was to analyze the efficiency of each workstation design in relationship to the transaction. This was done in two phases - the first phase was a typical baseline transaction analysis, recording timed activities throughout the transaction and the second phase was a physical position and motion analysis. Data was gathered at two Atlanta area Office Depot sites. Each site used a unique check stand configuration, both using SYMBOL LS model hand held scanners for itemization.

Sams

This study was divided into two parts. The first part divided the analysis into three sections: what the customer was doing, what the cashier was doing, and what the equipment did. The second part was concerned with three different aspects of the transaction itself: the transaction as a whole, the itemization, and finalization.

Kroger: NCR 7880 vs. Spectra Physics 950

The purpose of this study was to compare the difference of the two scanners. The analysis for this study was concerned only with the scanning part of the transactions from the first item to the last. No analysis was done on finalization.

Meijer: NCR 7870 vs. Spectra Physics Magellan

The purpose was to compare the performance of the two different scanners. For this study we only needed to analyze the items being entered into the system; scanned and keyed.

Price Verifier Usability

The purpose of this test was to compare two different price verifying systems - the 7880 model and the 7890 model - and analyze the easability of certain bar codes in scanning. The test was carried out in the Human Factors room at AT&T GIS.

Albert Heijn

The purpose of this test was to quantify productivity and ergonomic differences between the new and old style checkstands at two Albert Heijn stores. Both store have NCR 7880 scanners, but are in different positions in each checkstands. The results will also influence scanner-scale needs. Activity (scanning, keying, price identification, time to wait for customer to go weigh) for produce was important. Many special occurrence activities were also looked at and documented.

On going projects

Lane Bryant

The purpose of this test is to establish a snapshot of current wrapstand activities, set baseline for comparison of existing terminal with 7450 (to be installed later in same store), gather justification for new wrapstand design, compile information to assist third party software developer in DynaKey/7450 application.

Students who worked on projects

Sears:

Harold Baro	Chong Pak
Manish Dodia	Caroline Ho
Jeff Driscoll	Christi Ruberti
Mash Handa	Sean Smith

Office Depot:

Manish Dodia	Caroline Ho
Jeff Driscoll	Christi Ruberti
Mash Handa	Sean Smith

Kroger:

Jock Barnes	Caroline Ho
Manish Dodia	Louise Penberthy
Jeff Driscoll	Christi Ruberti
Mash Handa	

Sams:

David Brown	Frank Dunn
Vince Calhoun	Mash Handa
Manish Dodia	Caroline Ho
Jeff Driscoll	

Meijer:

David Brown	Frank Dunn
Vince Calhoun	Mash Handa
Manish Dodia	Caroline Ho
Jeff Driscoll	

Price Verifier:

David Brown	Frank Dunn
Vince Calhoun	Mash Handa
Manish Dodia	Caroline Ho
Jeff Driscoll	Christi Ruberti

Albert Heijn:

- Leonard Baker
- David Brown
- Vince Calhoun
- Manish Dodia
- Jeff Driscoll
- Frank Dunn
- Caroline Ho

Lane Bryant:

- Leonard Baker
- Manish Dodia
- Jeff Driscoll
- Frank Dunn
- Caroline Ho

Equipment in lab

Computers

ITEM	MODEL #	SERIAL #	CLASS	TRACER #
NCR PCU 386	3507	15-19722803	3386	15-013218
NCR PCU 386SX	0116	17-20956664	3304	
Leading Edge WinPro 486e	CPC-2703U	0047040723 732		
Leading Edge WinPro 486e	CPC-2703U	0047040723 720		

TV'S

ITEM	MODEL #	SERIAL #
20" SHARP TV	20E-S50M	346962
20" SHARP TV	20E-S50M	346959
20" SHARP TV	20E-S50M	346965
20" SHARP TV	20E-S50M	348163
20" RCA TV	F20536EH	303616479
19" ZENITH TV	F1910B	922-02410180
19" ZENITH TV	F1910B	922-02410199
HITACHI 13" TV	CT1396VM	S2B010772
HITACHI 13" TV	CT1396VM	S1L007999

VCR'S

ITEM	MODEL #	SERIAL #
Samsung VCR	VR5703	6RACB08377
Samsung VCR	VR5703	6RACB08020
Samsung VCR	VR5703	6RACB07818
Sanyo VCR	VHR-5408U	45551553
Symphonic VCR	7860	D05212946
Mitsubishi VCR	HS-U31	U31059182
Toshiba VCR	M-432	74624042
GE VCR	VG-7920	915213206
JVC VCR	BR-7700U	15611749
RCA VCR	4R516	23464747

Miscellaneous Equipment

ITEM	MODEL #	SERIAL #
Leading Edge Monitor	CMC-1418AD	5011540202656
Leading Edge Monitor	CMC-1418AD	5011540100595
NCR Monitor	MCH-4335	20157847
Sony Monitor	CPD-1302	7016738
Leading Edge Keyboard	BTC5369	K406008248
Leading Edge Keyboard	BTC5369	K406008274
Keyboard	2189001-00-411	00324656
NCR Keyboard		000867
Logitech Mouse	9F	LT042N01778
Microsoft Mouse		213044

Hewlett Packard Desk Jet Printer	500C	3206A34973
IBM Dot Matrix Printer	4202 001	47 0030741
GE Answering System	2-9876A	00117219
Panasonic Phone	KX-T2335	3ICEE65287

New Data Entry Tool

A new, more automated data entry spreadsheet was developed for Microsoft Excel and Word. The new spreadsheet contains macros which use both the workbook format and Visual Basic capabilities of Microsoft Excel. The macros provide functions to fill in repeated times or codes, check for and flag negative task times, enter counts and concurrent times, paste data to Word and automatically format the data for subsequent analysis by SeqDec. The spreadsheet information provided to the analysis laboratories is provided below.

New Data Entry Tool: Instructions

Introduction

The new data entry tool is a more automated version of the current Excel data entry tool. This tool takes advantage of both the workbook (consisting of multiple worksheets) format and Visual Basic capabilities of Excel 5.0. Specialized pull-down menus are available to perform data entry related tasks, while unnecessary Excel functions are hidden. Visual Basic macros are used to speed entry of times and codes, to identify certain errors, to paste the data to a Word file, and to format the data correctly for subsequent analysis by SeqDec.

Installation

The new data entry tool requires macros in both Microsoft Excel and Word. Therefore, two files must be installed for the tool to work.

Installing DATATOOL.XLS

1. Using the Windows file manager, create a new directory within the existing Excel directory called DT (directory will be c:\excel\DT)

2. Copy the file a:DATATOOL.XLS to c:\excel\DT

3. It is also a good idea to save a copy of this file in another directory (say, c:\excel\DTBACK)

4. Create a Windows icon that will automatically run DATATOOL.

   a. while in the Windows Program Manager, select the **New** choice from the **File** menu. Select New *Program Group*, click **OK**. Type in a description (probably Data Entry, or something like that). Click **OK**. Now you have a new window called Data Entry. Click on this window to make sure it is highlighted (selected).

   b. Select the **New** choice from the **File** menu again. This time, select New *Program Item*. Fill in c:\excel\DT\DATATOOL.XLS in the Command Line box. Fill in anything you like in the description box (this is what the icon will be called). Click OK. You should now have an icon that will directly run DATATOOL.

5. Change the property of DATATOOL.XLS to **read-only**. Open the file manager in Windows, change to the c:\excel\DT directory, and click once on the DATATOOL.XLS file. From the **File** menu, select the **Properties** menu choice. Click on the Read Only box so that the "X" in the box is removed. Click **OK,** and close the file manager.

DATATOOL is now installed as a read-only Excel file that can be run directly by clicking on a windows icon.

Installing DATATOOL.DOT

1. Copy the file a:DATATOOL.DOT into the c:\winword\startup directory. This will cause the necessary macros to be available when you run Word.

2. In Word, check to make sure that Word is using the macros contained in this file.

Select the **Macro** choice from the **Tools** menu. Make sure that "All active templates" is selected in the Macros Available box (this should be the default, so it is not necessary to check this every time you perform data entry).

Data Entry

Menu Commands

Now, start the DATATOOL program by clicking on the icon you just created. Notice the menu bar has fewer options than are normally available in Excel, and some are different. Here is a description of the new menu commands.

Transaction Menu

Enter Start Time: brings up dialog box asking for start time in specified format, enters start time in appropriate cell.

Enter Final Code: brings up dialog box asking for final time in specified format, enters final time in appropriate cell. Also enters the "F" code in the appropriate cell.

Fill in times and codes: If there is a blank cell left beneath a cell containing hour, minute or code, this copies the cell to the one beneath it. Use to fill in hours, minutes, duplicate codes.

Enter Counts: brings up a dialog box and new sheet to enter count mnemonics and counts.

Enter concurrent times: brings up a dialog box and new sheet to enter concurrent mnemonics and times.

Arrange and paste: arranges times, codes, counts, and concurrent times into the correct format, pastes these to an open Word file, then reformats the data in Word. If there are any negative times, an error message will appear and the times will be highlighted in red.

New Transaction: clears the coding sheet to allow entry of a new transaction.

Utility Menu

Insert Row: Inserts a new row on the coding sheet and copies the appropriate formulas and settings into the new row.

Delete Row: Deletes the highlighted row or rows, and copies the appropriate formulas and settings into the new row.

Change Count/Concurrent Codes: brings up a sheet containing count and concurrent mnemonics to allow changes or additions. Used at the beginning of each study.

Dialog Boxes

Some of the menu commands bring up dialog boxes to help you enter data. Here is a description of how all of the dialog boxes work.

<u>Enter Start time:</u>

Enter the start time in the format shown - you must type in the colons and period. Hit **OK** to enter this time on the coding sheet, or **Cancel** to close the dialog box without entering the start time.

<u>Enter Final code:</u>

Enter the final time in the format shown - you must type in the colons and period. Hit **OK** to enter this time and the "F" code on the coding sheet, or **Cancel** to close the dialog box without entering the final time and code.

<u>Enter Counts</u>:

Click on the count mnemonic, then on the count number from the scrolling lists. Hit **Add to Sheet** to enter the count on the count coding sheet. Hit **OK** to return to the main coding sheet, saving the count data on the count coding sheet. Hit **Cancel** to clear the coding sheet and return to the main sheet without saving the count data.

Note: if you forget to enter a count once you have returned to the main coding sheet, just select the **Enter Counts** menu choice again - all saved count data will appear on the count coding sheet.

<u>Enter Concurrent Times</u>:

Click on the concurrent mnemonic from the scrolling menu. Then, type the start hour, minute, second, and tenth in the appropriate boxes. The End Time boxes will automatically update to reflect the start times - so you'll probably only have to change the seconds and tenths. You can use the **TAB** key to move from box to box. Hit **Add to sheet** to add the concurrent mnemonic and time to the concurrent coding sheet. Hit **OK** to return to the main coding sheet, saving the concurrent data on the concurrent coding sheet. Hit **Cancel** to clear the coding sheet and return to the main sheet without saving the concurrent data.

Note: if you forget to enter a concurrent once you have returned to the main coding sheet, just select the **Enter Concurrent Times** menu choice again - all saved concurrent data will appear on the concurrent coding sheet.

<u>Changing the Available Count and Concurrent Codes:</u>

At the start of a new study, it is necessary to change the count and concurrent mnemonics to match those of the new study. To make these changes, the DATATOOL.XLS file must be change from a read-only file to a read-write file. To do this, exit from Excel. Open the file manager in Windows, and click once on the DATATOOL.XLS file. From the **File** menu, select the **Properties** menu choice. Click on the Read Only box so that the "X" in the box is removed. Click **OK,** and close the file manager.

Now, run the DATATOOL program. Select the **Change Count/Concurrent Codes** choice from the **Utility menu.** A sheet containing list of count and concurrent mnemonics will appear. Delete any old codes you won't be using. Then, as indicated on the sheet, enter the new codes in the highlighted columns. Hit **Finished: Return to Main Sheet** when you are done. Then, choose the **SAVE** option from the **File** menu (or use the save icon) to save the new codes. Exit from Excel.

Remember to change the status of the file back to Read-only by opening the file manager, selecting the DATATOOL.XLS file, choosing the **Properties** menu choice from the **File** menu, and clicking on the Read Only box.

Typical Entry Sequence

Try out the new program. First, you must start Microsoft Word running. Then, follow the instructions below.

1. Enter the start time by selecting the **Enter start time** choice from the **Transaction** menu. Remember to use the colons and period as indicated. The hour, minute, second and tenth columns for the start time must also be filled in the first row.

2. Enter the times and codes. To save time, only enter the hour, or minute time when it changes (ex. if the hour is always a "1", just enter that in the first row and leave that column blank for the rest of the rows.). It is also only necessary to enter the first mnemonic in a series of repeated mnemonics. Task times are automatically calculated, but may not look right until step 4 if you left any cells blank.

If you forget a task, you can insert a row or row by clicking on the number of the row at the left of the worksheet and selecting the **Insert Row** choice from the **Utility** menu. This will insert a new row ABOVE the row you selected.

To delete a task row, click on the row number and choose the **Delete Row** choice from the **Utility** menu.

3. Enter the final time and code by selecting the **Enter final code** choice from the **Transaction** menu. Remember to use the colons and period as indicated.

4. Select **Fill in times and codes** from the Transaction menu. This fills in any hour, minute, second, or code cells you left blank in step 2.

5. Select the **Enter Counts** choice from the **Transaction** menu to enter the necessary counts.

6. Select the **Enter Concurrent times** from the **Transaction** menu to enter the necessary information about concurrent tasks.

7. Select **Arrange and Paste** from the **Transaction** menu to combine the task codes and times, counts, and concurrent information. The data is automatically pasted to the Word file that you have open, and is automatically formatted for subsequent analysis in SeqDec. If any of the task times are negative, the data will not be pasted, an error box will appear (click OK to remove it), and the negative time will be highlighted. Fix the incorrect Hour, Minute, Second, or Tenth cell, (the cell which contained the negative task time will STAY RED) and select the **Arrange and Paste** choice again.

Remember to periodically switch to Word, and **SAVE YOUR WORD FILE**. DATATOOL **does not** save the Word file for you. Remember that this file must be saved as a Text file for subsequent analysis by SeqDec.

8. Select **New Transaction** from the **Transaction** menu to clear your data and enter a new transaction.

<u>If you have a problem....</u>

Please also remember that this program is not entirely bug-proof (but should not be having problems, either). However, the file you are working on is still just an Excel File (just happens to be called DATATOOL.XLS).

Some help if you have a problem:

First, to save the transaction you've been typing in, use the **SAVE AS** command and save the file with a new name (gets around the read-only restriction). Also, remember to save your Word file separately.

Using the Edit menu, **copy** the portion of your data in the hours, minutes, seconds, and tenths columns (first highlight the data in these columns, then choose **Copy** from the **Edit** menu). **DO NOT HIGHLIGHT/COPY THE CODE COLUMN** (because of some hidden columns performing calculations, only the A-D columns should be copied as a block.). Next, choose **Close** from the **File** menu. Now, choose **Open** from the **File** menu. Open the DATATOOL.XLS file (in the c:\excel\DT directory). Paste your data into the correct location on the new spreadsheet. Unfortunately, this does not save the mnemonics you have typed in, only the times.

Restoring other menu choices:

Sometime (but I'm not sure why) you may need to restore the Excel menu functions that have been deleted.

From the **View** menu, select the **Toolbars** choice. Click on the Visual Basic choice, and click **OK**. Now, look at the Visual Basic toolbar that has appeared. There is an icon that looks like a pull-down menu. Click on that icon. A menu-editor dialog box should appear.

Click on the "Show Deleted items" in the lower left-hand corner of the box. "Grayed out" menu choices should appear in the scrolling lists of menu items. Click on one of the "grayed out" choice that you want to undelete, then click on the undelete button in the top-right corner of the dialog box. Repeat for all the choices you want to undelete. Click **OK**. Now, the old menu choices should be back.

Any questions? Find any bugs?

Amy Bisantz 404-894-4318 (my office)
404-894-0052 (video lab)
404-993-7053 (home)

bisantz@chmsr.gatech.edu (best way to find me)

Exploring New Analysis Methodologies

The following presentation was given on January 24 to members of the Human Factors group at ATT-GIS. It described activities conducted through 1994 to identify and explore the feasibility of possible additions to the current analysis process. These activities included:

1. Interviews with engineers to identify aspects of the current process and suggestions for improvements. A detailed summary of the interviews follows later in this report.
2. Review of literature relevant to field study and videotape analysis.
3. Recommendations for a more automated video analysis/data entry tool.
4. Feasibility studies to test two new analysis methods: analysis from different points of view, and analysis using hierarchically organized mnemonics at varying levels of detail. Results and conclusions from these studies are provided.
5. A description of some further methodologies which might facilitate and integrated study of the cognitive, social, and systems aspects of environments. A more complete literature review describing these issues follows later in the report.

Exploring New Analysis Methods

Ann Bisantz
Georgia Institute of Technology

Introduction

- Current analysis costly, time consuming
  - » fine grained analysis
- Focus on physical behaviors may miss other aspects
  - » cognitive issues
  - » communication, information flow
  - » organizational and social issues
- Transaction model cannot answer all relevant questions
  - » parallel tasks
  - » other than POS activities
  - » when transaction spread out in time, more than one customer served at once

Outline

- Interviews
- Literature Review
- Feasibility Studies
- Future Methodologies

Interviews -Procedure

- Seven engineers, one analyst manager interviewed
- Obtain information about current process, possible changes and additions

Interviews - Procedure

- Questions included:
  - » current process, statistical analysis, quality checks
  - » project types, focus; project goals, future analysis needs
  - » customer goals and expectations
  - » information sources for analysis
  - » mnemonics, hypotheses formulation
  - » role of experience, data in making recommendations
  - » questions not being answered by current process
  - » varying detail, generalizing across studies, work sampling
  - » difficulties with current process
  - » quality checks, ties to raw data

Interviews - Results

- Additional analysis needs
  - » cognitive issues
  - » qualitative descriptions of tasks (e.g. error types, information available to cashier)
  - » field experiments
  - » biomechanical studies
  - » non-POS activities
  - » parallel activities

Interviews - Results

- Information Sources
  - » video tapes
  - » informal interviews
  - » training manuals, training participation
  - » keyboard layout
  - » register tapes
  - » systems information
  - » store reports of transactions
  - » biomechanical information

Interviews-Results

- Analysis Process
  - » questions with data reliability
  - » quality checks time consuming
  - » process should become more iterative
  - » teams need to be involved in entire process
  - » standardizing mnemonics, having team specialist to reduce learning time

Interviews - Results

- Difficult to compare across studies, products
- Difficult to analyze usability
  - no keystroke, screen display information captured
- Customer goals and expectations
  - some idea of problems that may exist
  - not familiar with, do not request this type of analysis
  - but, transaction models provide customers with detailed information about their process
- More feedback from customers needed

Interviews - Results

- Observation necessary to develop hypotheses and mnemonics
  - » not always time for extensive interviewing, observation at site, review of tapes
  - » may result in repeating mnemonics, hypotheses from past studies
- Experience also plays large role
  - » forming hypotheses (clues about what could cause a problem)
  - » developing mnemonics
  - » making recommendations
    - – data used to support conclusions, find instances of proof
    - – comparisons with other retailers

Interviews - Results

- More data collected, analyzed than used in recommendations
  - » more data on tape than analyzed
  - » over-detailed analysis
    - – lack of specific goals
    - – analysis process
- Changing detail level
  - » many tradeoffs (detail, specificity for speed, generalization)
  - » several passes
  - » vary within one pass

Conclusions and Recommendations

- Preserving information, generalizing across studies
  - » currently informal
  - » interview question bank
  - » standard pool of mnemonics
  - » results for future comparison
  - » only reuse when appropriate
- Capturing other types of information
  - » informational, organizational, cognitive aspects
  - » parallel activities
  - » sequential nature of activities
  - » causes of errors, usability

Conclusions and Recommendations

- More focused hypotheses, mnemonics to analyze only information of interest
  - » hypotheses should precede analysis (experience and observation)
  - » change level of detail
  - » categorical data (tallies)
- Changes to analysis process
  - » more interative, early feedback
  - » allot time for changes, fine tuning early in study
  - » brief teams on goals, importance of certain mnemonics
  - » more information from teams regarding special occurrences, possibilities for further analyses
  - » have cashiers view tapes

Literature Review

- Looked at literature, studies that dealt with how to collect, analyze data from real systems
- Laws and Barber, 1989
  - » important to have several levels of coding
  - » can filter, interpret low level actions using higher level context
- Woods, 1987
  - » joint person-machine system is the relevant object for study
  - » study tools, artifacts and their implications about cognitive processes vs. current behavioral, equipment descriptions

Literature Review

- Woods, 1993
  - » use process tracing methods to study incidents in real world systems
  - » description based on many types of data
    - – verbal protocols (problems in retail environment?)
    - – respective protocols (have cashiers view tapes)
    - – records of process, data aquisition, communication
- Woods and Sarter,
  - » systems approach
  - » measurement techniques sensitive to phenomena of interest

Literature Review

- Suchman, 1990
  - » interaction between humans and machines linguistic in nature
  - » problem of artifact design is a problem of communication
  - » often, artifacts designed using "planning" model of user where a situated action model more appropriate
  - » thus, coherence of users actions often unknown to system
- Jordan and Henderson, draft
  - » don't analyze for "everything," instead - is analysis adequate for task at hand?
  - » video tapes replace observer bias with machine bias
  - » use several passes to identify important occurances, don't use predetermined coding schemes (bias)

Analysis Tool: Recommendations

- Combine videotape control, viewing, coding, and analysis
- Support reuse of information
  - » standardization of mnemonics
  - » results and recommendations
- Support analysis of parallel activities
  - » concurrent, parallel activity streams
  - » different descriptions of same activity
- Allow task descriptions at multiple levels of detail
- Support error-checking
- Provide statistical tools

Feasibility Testing

- Reanalyzed data from Sam's Warehouse study (Spring, 1993) using:
  - » Different Points of View (POV study)
  - » Hierarchically organized mnemonics (Hierarchy study)

POV Study

- Created three sets of mnemonics to describe actions of the cashier, customer, and equipment respectively
- Questions:
  - » Is this type of study possible?
  - » Does it provide useful information about parallel activities that might otherwise be missed?
  - » Can it help improve accuracy in cases where there are parallel activities?

POV Study - Procedure

- Analysts used the three sets of mnemonics to describe each transaction (87, 56, 58 transactions each)
- One analyst kept track of time to analyze transactions,using two different analysis methods
  - » parallel
  - » sequential
- By examining data files from the original study and the 3 POV used here, data from the same 49 transactions were analyzed to form transaction models

POV Study - Results

- Time analyses
- Transaction Models
- Timeline analyses

POV Study - Results

- Transaction Time
  - » combined analysis on all data (from POV, Hierarchy, and original study) showed no significant difference in transaction times ($F_{6, 410}$, p = .617)
  - » analysis on data from 49 transactions used for POV analysis showed?

	Mean	Std Dev	Min	Max
Cashier	96.37	56.96	33	299
Customer	96.61	57.33	34	300
Equipment	82.61	57.59	24	279
Original	97.65	58.3	34	299

POV Study - Results

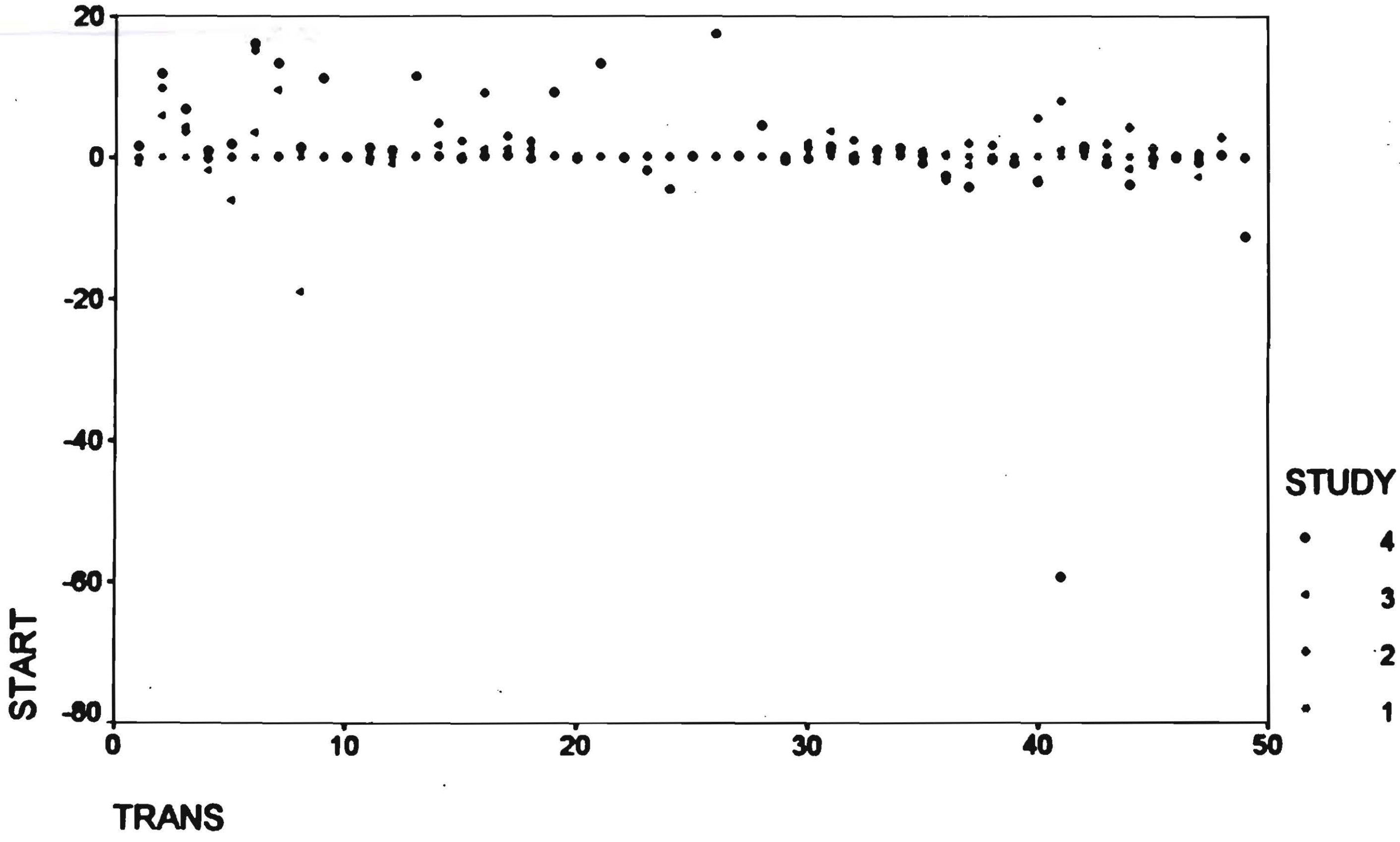
- Analysis of start and end times
  - » start times not significantly different
  - » end times were significantly different
  - » post-hoc tests showed equipment POV end time was different than other POV

End Time Deviations from Cashier POV

Study	Mean	Std Dev
Cashier	0	0
Customer	0.19	2.98
Equipment	-12.09	10.09
Original	1.91	5.78

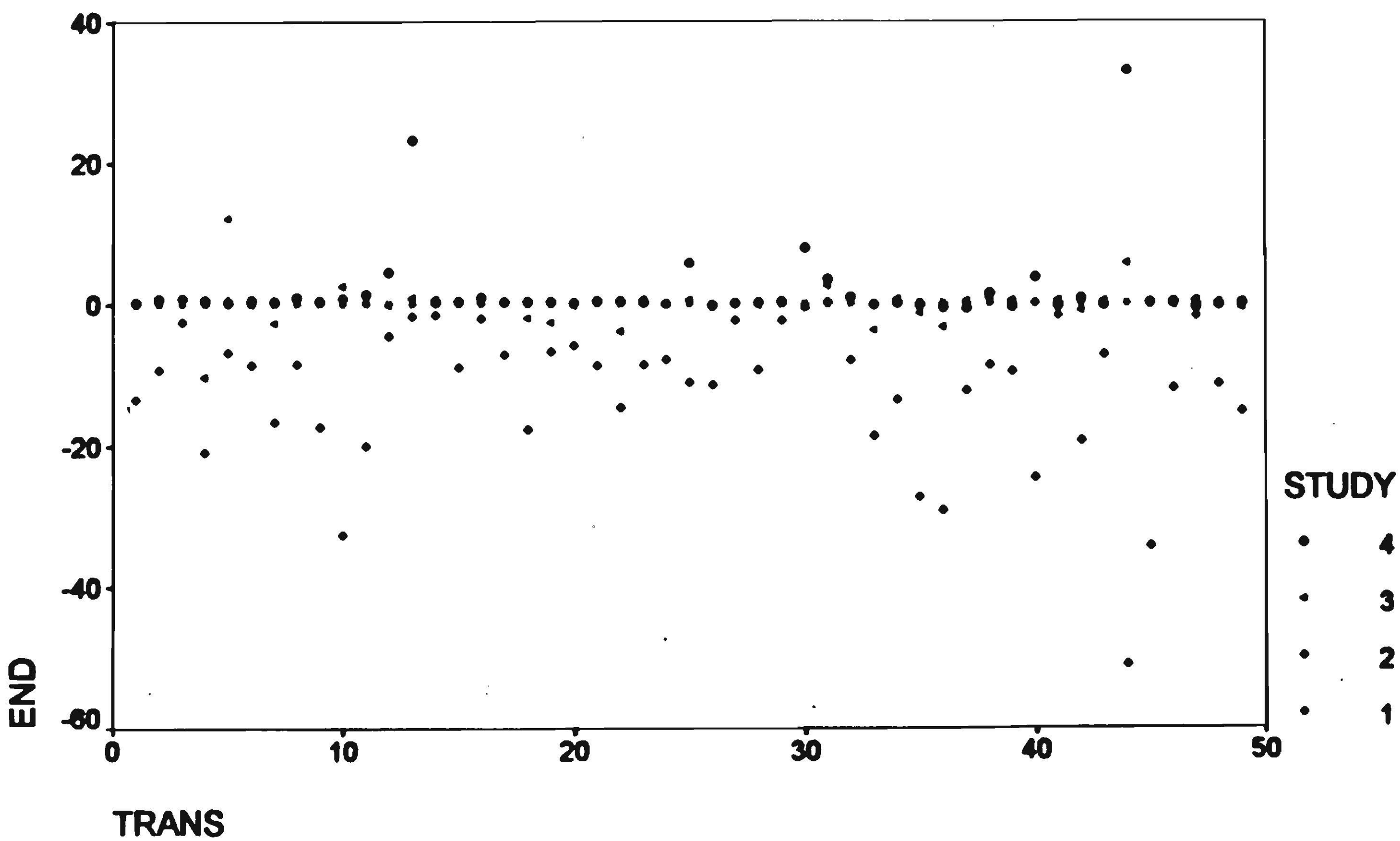
POV Study - Results

- Scatter plot of start times



POV Study - Results

- Scatter plot of end times

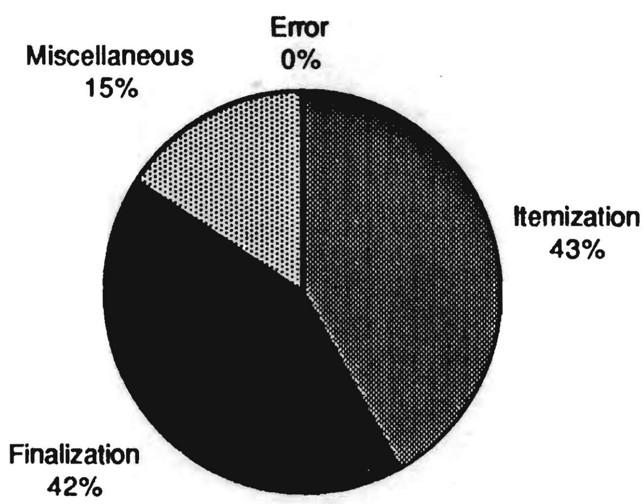


POV Study - Results

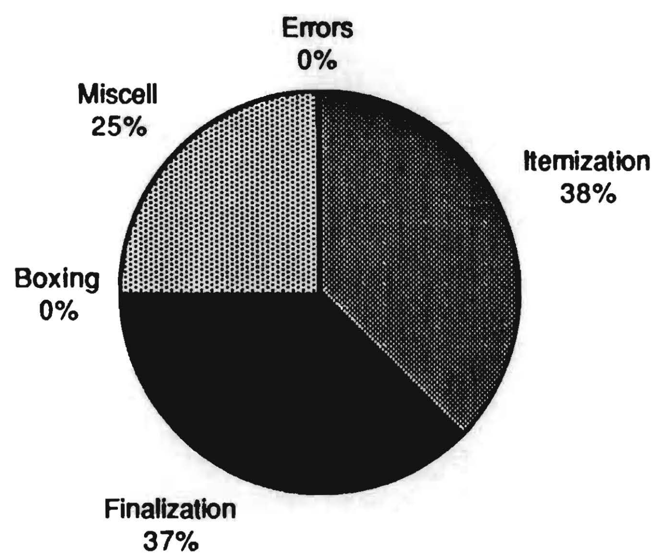
	Cashier	Customer	Equipment	Original
Itemization	36.12	6.13	22.85	40.95
Finalization	35.93	20.57	12.36	41.47
Miscell	24.13	37.42	47.2	15.09
Errors	0.23	n/a	0.2	0.15
Boxing	0	1.35	n/a	0
Can't See	n/a	31.15	n/a	n/a
It, no hand	n/a	3.65	n/a	n/a
Mi, no hand	n/a	31.15	n/a	n/a
hand	n/a	8.75	n/a	5.67
Sum	96.41	96.62	82.61	97.66

POV Study - Models

Original Study: 97.66 seconds

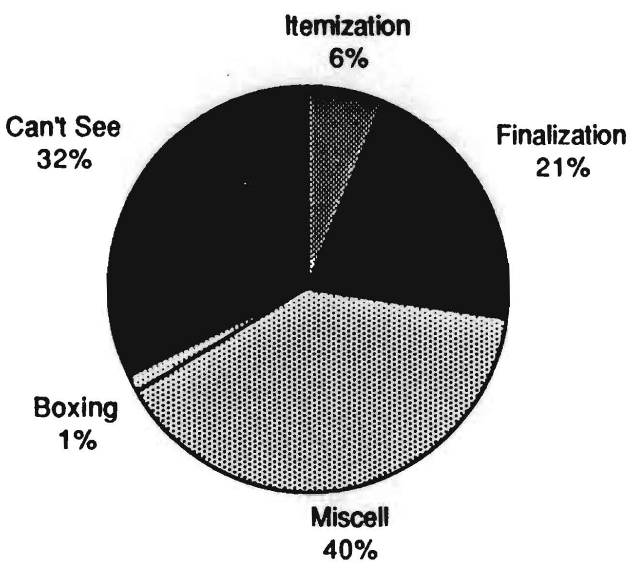


Cashier: 96.41 seconds

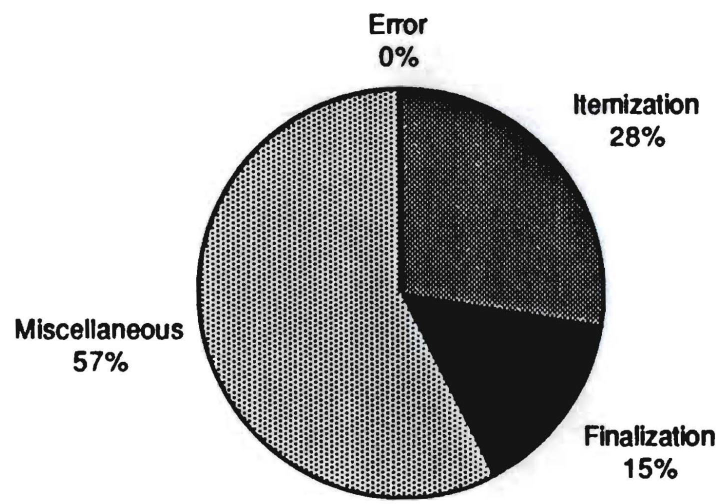


POV Study - Models

Customer (no hand.): 96.62 seconds

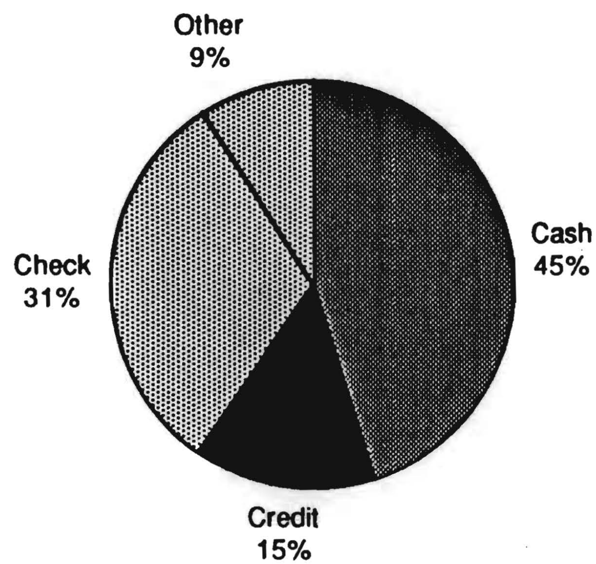


Equipment: 82.61 seconds

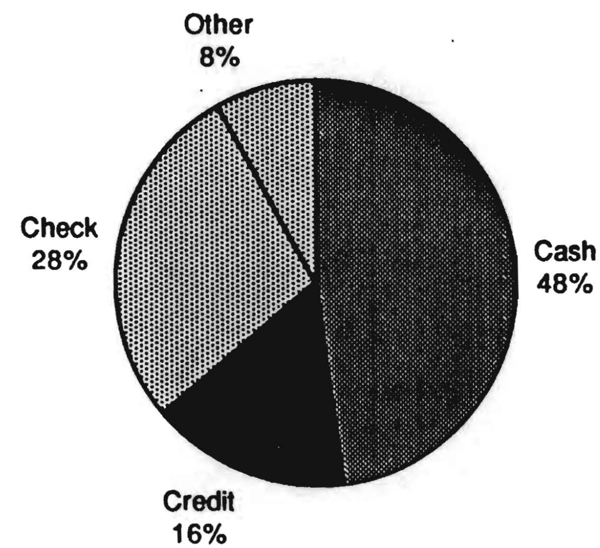


POV Study - Models

Original, Finalization: 41.47 seconds

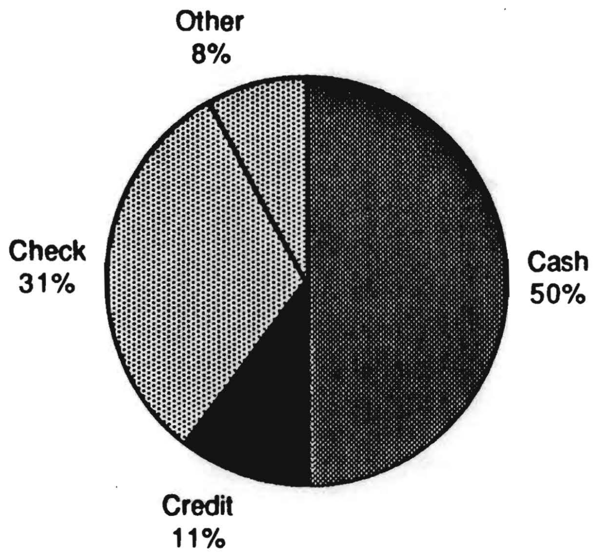


Cashier, Finalization: 35.93 seconds

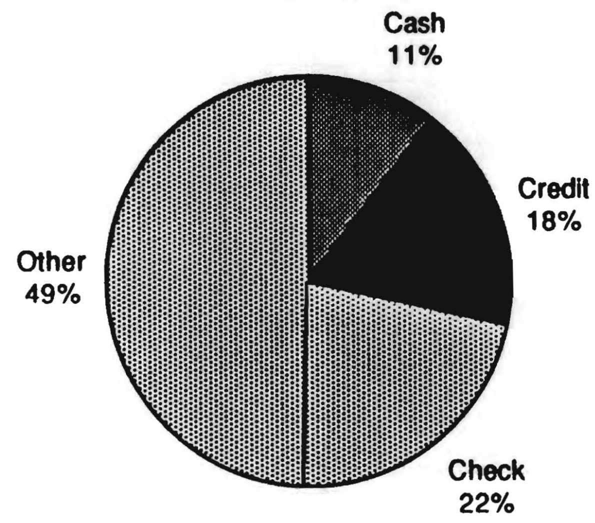


POV Study - Models

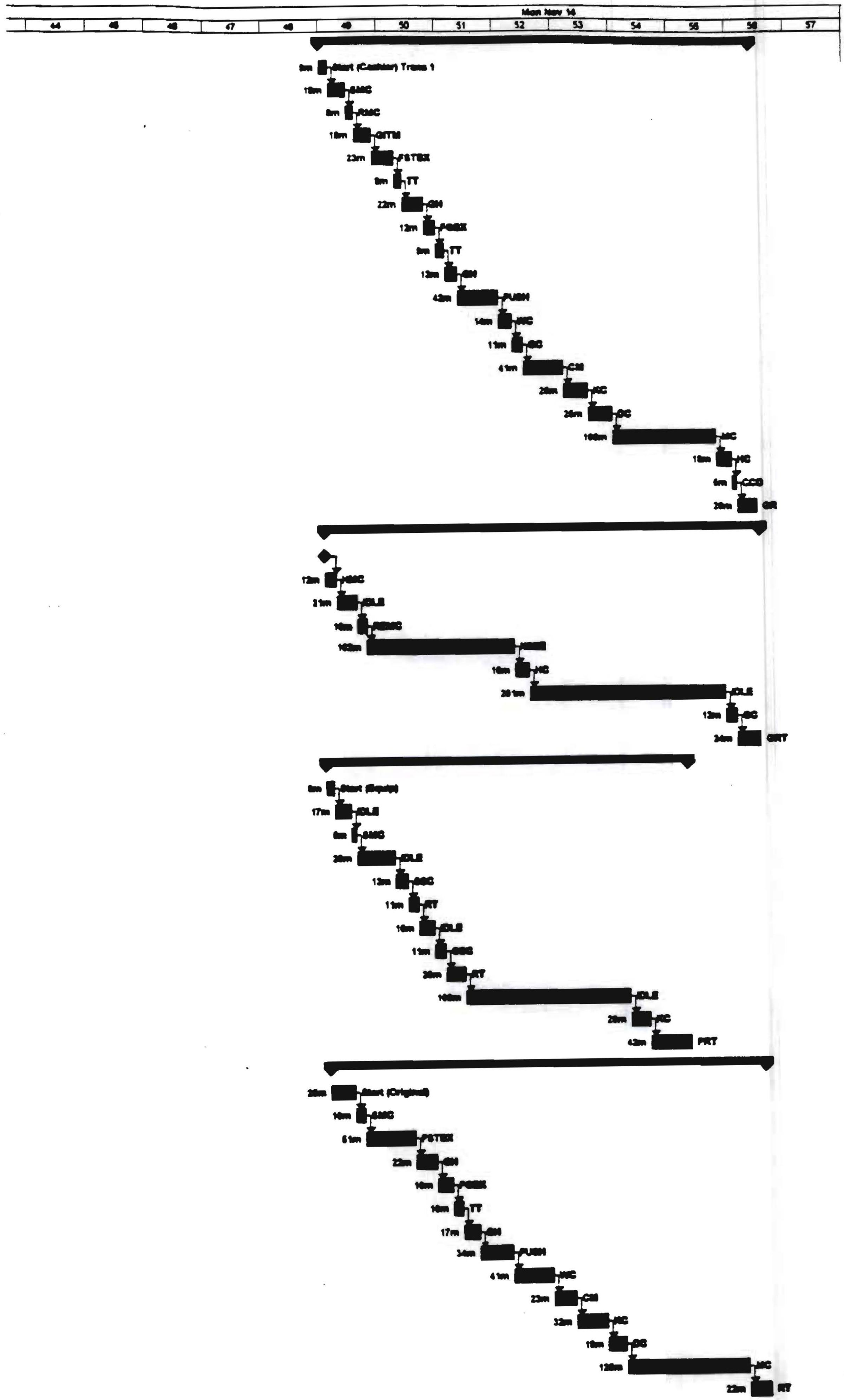
Customer, Finalization: 20.57 seconds



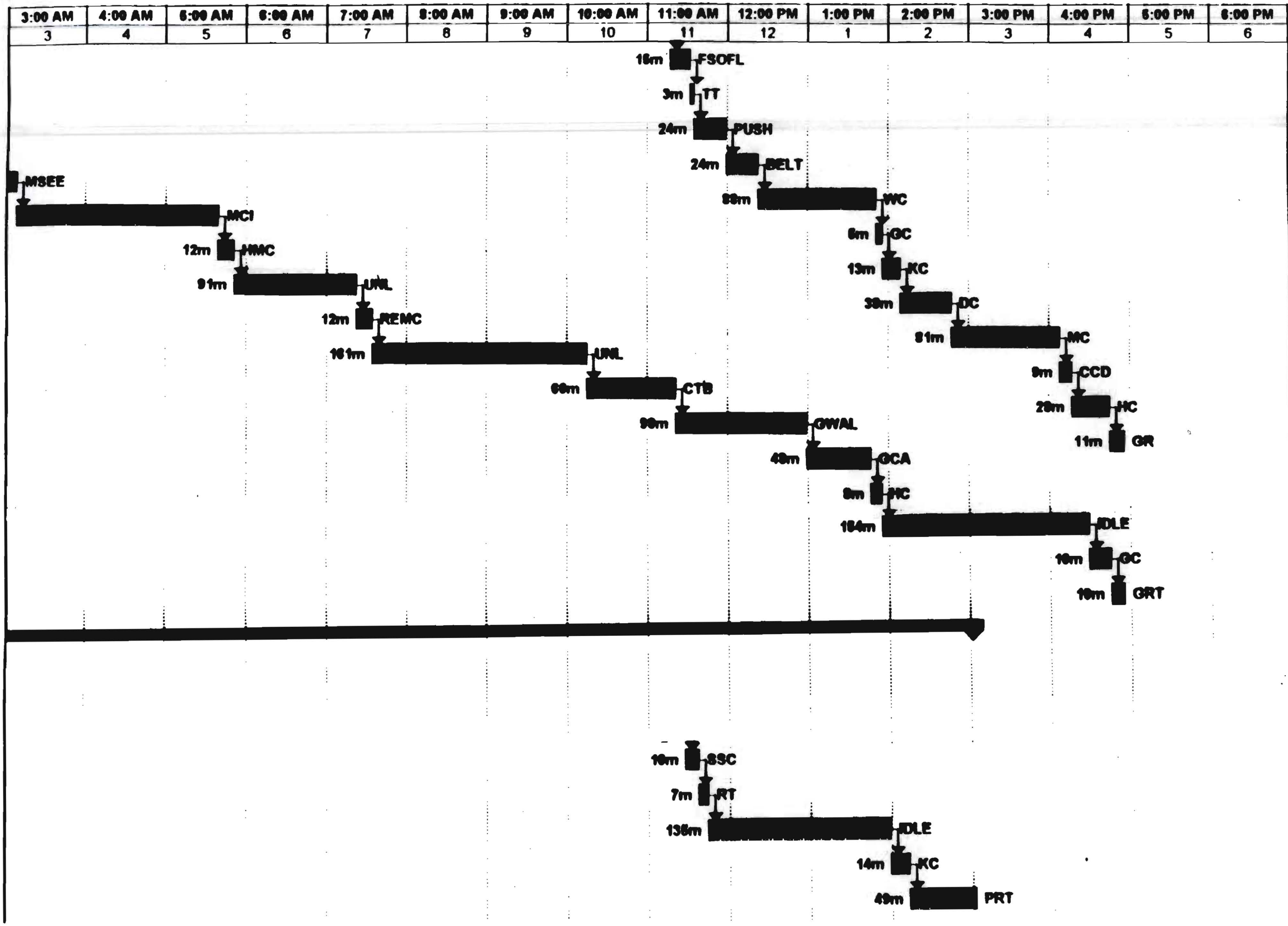
Equipment, Finalization: 12.36 seconds



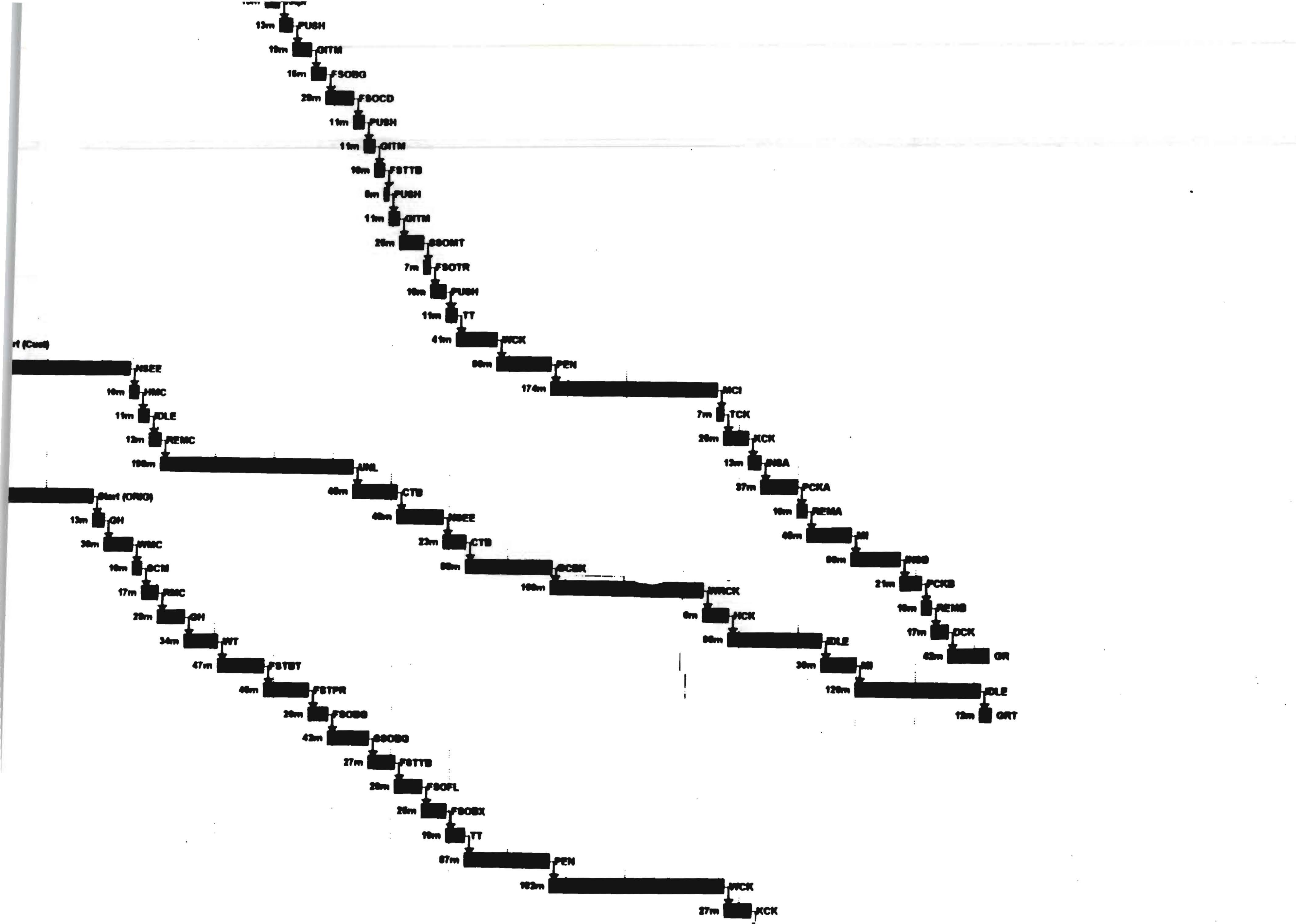
POV Study - Timelines



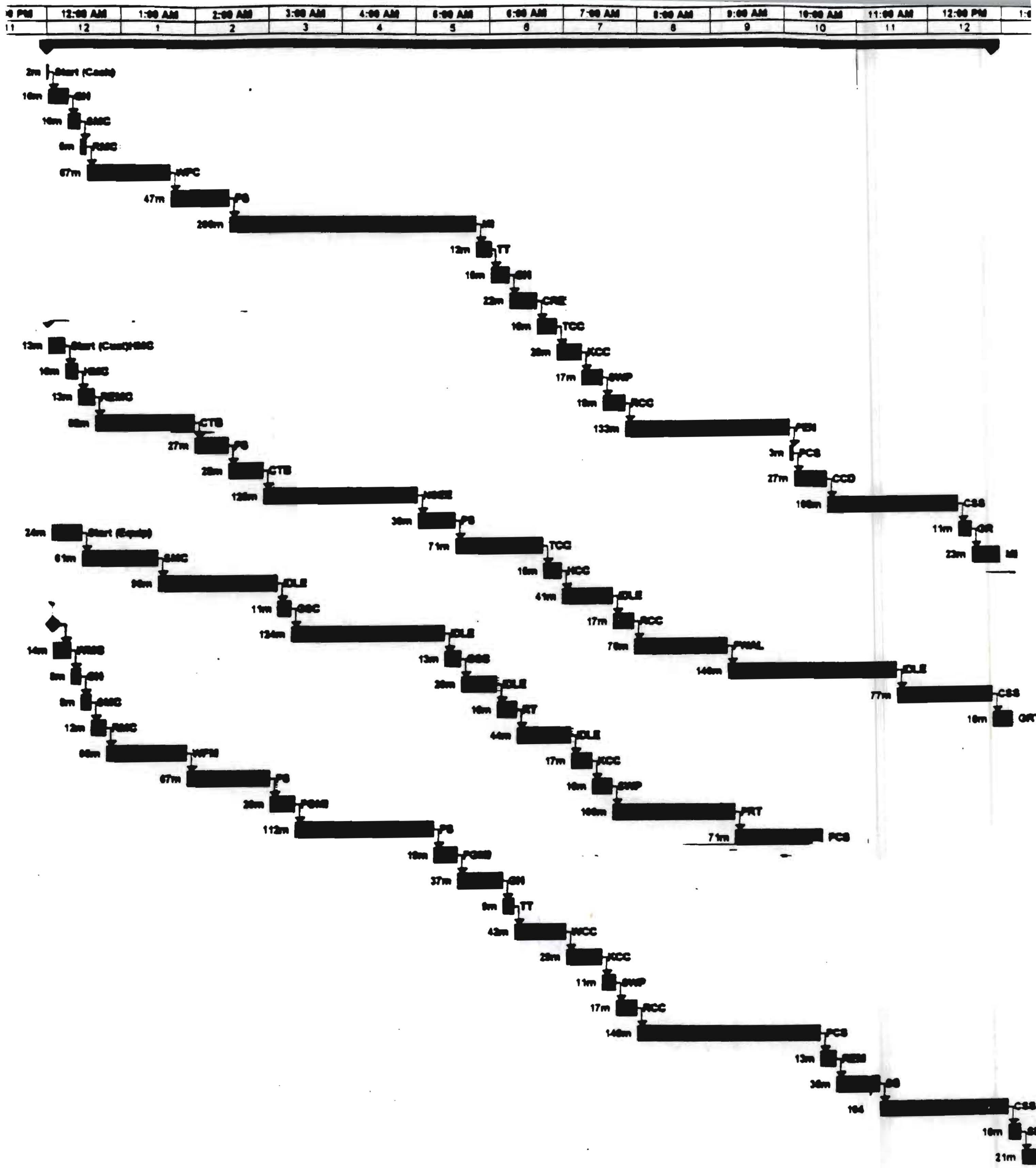
Mon Nov 14
44
45
46
47
48
49
50
51
52
53
54
55
56
57
Start (Cashier) Trans 1
TT
GH
PUSH
Start (Equip)
IDLE
Start (Original)
FSTEX
PUSH



3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
FSOFL
3m
TT
24m
PUSH
24m
BELT
MSEE
WC
MCI
GC
12m
HMC
13m
KC
UNL
DC
12m
REMC
MC
UNL
9m
CCD
CTB
HC
GWAL
11m
GR
GCA
HC
IDLE
GC
GRT
SSC
7m
RT
IDLE
14m
KC
PRT



13m PUSH
19m GITM
16m FSOBG
29m FSOCD
11m PUSH
11m GITM
10m FSTTB
8m PUSH
11m GITM
26m SSOMT
7m FSOTR
10m PUSH
11m TT
41m WCK
56m PEN
174m MCI
7m TCK
26m KCK
13m INSA
37m PCKA
10m REMA
46m MI
56m INSB
21m PCKB
10m REMB
17m DCK
42m GR
NSEE
10m HMC
11m IDLE
12m REMC
199m UNL
40m CTB
48m NSEE
23m CTB
88m SCSK
158m WRCK
6m NCK
96m IDLE
36m MI
126m IDLE
12m GRT
Start (ORIG)
13m GH
30m HMC
10m SCM
17m RMC
28m GH
34m WT
47m FSTBT
46m FSTPR
20m FSOBG
42m SSOBG
27m FSTTB
28m FSOFL
26m FSOBX
19m TT
87m PEN
182m WCK
27m KCK


12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
12
1
2
3
4
5
6
7
8
9
10
11
12
2m Start (Cash)
16m
16m
6m
67m WPC
47m PS
12m TT
16m
22m CRE
16m TCC
28m XCC
17m SWP
18m RCC
133m
3m PCS
27m CCD
168m CSS
11m GR
23m
13m
16m
13m
27m PS
28m CTS
128m
36m PS
24m Start (Equip)
61m SMC
71m TCC
16m XCC
41m IDLE
17m RCC
11m GSC
124m IDLE
13m
28m IDLE
16m RT
44m IDLE
17m XCC
16m SWP
166m PRT
71m PCS
148m IDLE
77m CSS
16m GRT
14m
8m
9m
12m RMC
67m PS
26m
112m PS
18m
37m
9m TT
42m WCC
29m XCC
11m SWP
17m RCC
148m PCS
13m REM
36m PS
164 CSS
16m SL
21m

POV Study - Results

- Method
  - sequential (trans 1-5, 36.8 min/trans; trans 11-20, 14.9 min/trans)
  - parallel (trans 6 -10, 20 min/trans; trans 21-30, 21.8 min/trans)
  - start and end times appeared to be more accurate for parallel method

POV Study - Conclusions

- Provides new picture of transaction
- May provide more accurate descriptions of activities
- Different POV provides explanatory power
- Parallel method seems superior based on preliminary data
- Training on transaction start and end times necessary

Hierarchy Study

- Created hierarchically organized mnemonic set which could be used to describe transaction activities at more or less detail
- Questions:
  - » Is it possible to structure the mnemonic set hierarchically to allow for standardization of mnemonics for future studies?
  - » Can a variable-detail study be performed accurately?
  - » Does this analysis save time by reducing description of unnecessary detail?

Hierarchy Study - Mnemonics

- Arranged mnemonics hierarchically
  - » Before Transaction
    - – sign on, wait for customer
  - » Itemization
    - – scanning & keying, item handling, error handling
  - » Finalization
    - – cash, check, charge payments, item handling, error handling
  - » Administrative
    - – supervisor time, equipment faults, cash drops, communication
- Tasks were nested - e.g. item handling (shuffle item) during itemization, finalization given different codes

Hierarchy Study - Mnemonics

Example: 3 levels of detail for Finalization

Finalization - after total key to end, except for administrative - FI

Finalization
- **payment activities**
  - cash CASH
  - check
    - keying activities for check - KCK
    - other terminal activities - TRCK
    - check activities - cashier touching check, waiting for printing on check, writing on check CHK
    - id activities - confirming ID - CID
    - receipt activities - wait, tear, printing, handing, bagging receipt - RCT
    - cashier-customer interaction - waiting for id, check, etc. INT
  - charge CHG
- **item handling - after total key**
  - cart HCRT
  - belt (on belt) HBLT
  - hanger - HTA
  - fold - FTA
  - bagging - BGA
  - boxes - BXHA
  - slide/shute SLIA
- **changes after total key CHAT**

Finalization
- **payment activities**
  - cash
    - keying activities
      - key in cash - KC
    - other terminal activities
      - close cash drawer - CCDC
    - cash activities
      - count money received - CM
      - make change - both - MC
      - no change - NC
      - drawer cash - DC
    - receipt activities
      - wait for receipt to print - RTC
      - tear off receipt - TRC
      - hand customer receipt - GRC
      - put receipt in bag - BRC
    - cashier-customer interaction
      - wait for cash - WC
- **item handling - after total key**
  - cart
    - move items in cart - SHA
    - move cart - CTA
    - stoop to place something on bottom of cart - UCA
    - load items, bags in cart - LOAD
  - belt
    - shuffle items on belt - SHBEA
  - hanger - HTA
  - fold - FTA

Hierarchy Study - Procedure

Three sets of mnemonics:

	# Trans.	**Before Tran**	**Itemization**	**Finalizatio**	**Administrati**
Hierarchy 1	100	no detail	no detail	moderate	full detail
Hierarchy 2	75	full detail	moderate	full detail	no detail
Hierarchy 3	47	no detail	full detail	no detail	moderate

Transaction models computed from this data

Hierarchy Study - Results

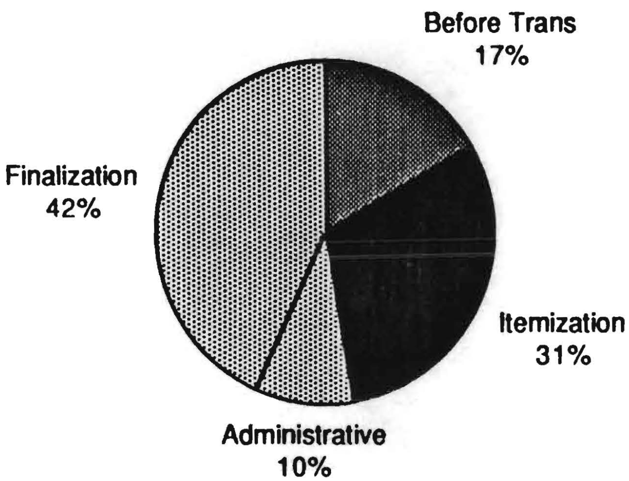
- Comparison of times
- Comparison of transaction models

Hierarchy Study - Times

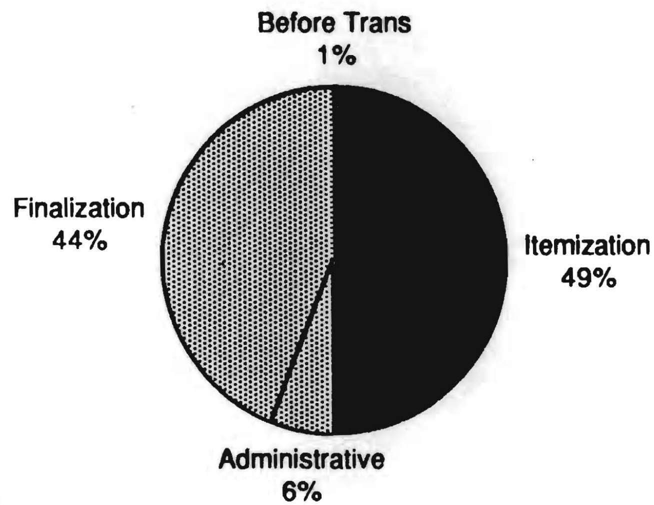
	Hierarchy 1	Hierarchy 2	Hierarchy 3
Before Trans	**17.13**	**1.8**	**0.53**
Itemization	**31.52**	**47.85**	**50.02**
Cash	25.9	19.58	n/a
Check	10.06	9.87	n/a
Charge	3.88	9.13	n/a
Final Pay	39.84	38.58	n/a
Handling	4.38	2.06	n/a
Changes	0	0	n/a
Finalization	**44.22**	**40.64**	**44.25**
Administrati	**10.04**	**7.76**	**5.79**
Sum	**102.91**	**98.05**	**100.59**

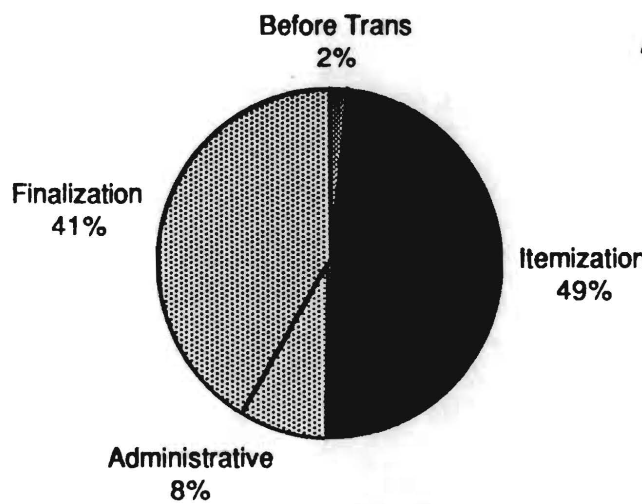
Hierarchy Study - Models

Hierarchy One: 102.5 seconds



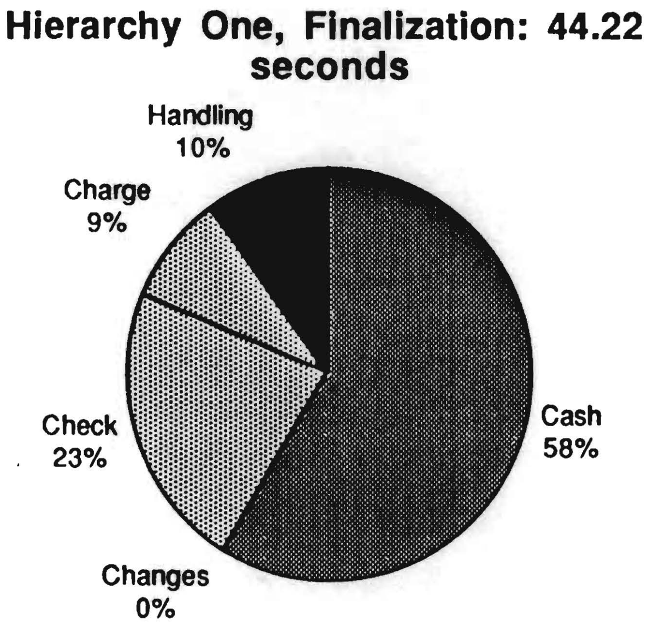
Hierarchy Three: 100.59 seconds

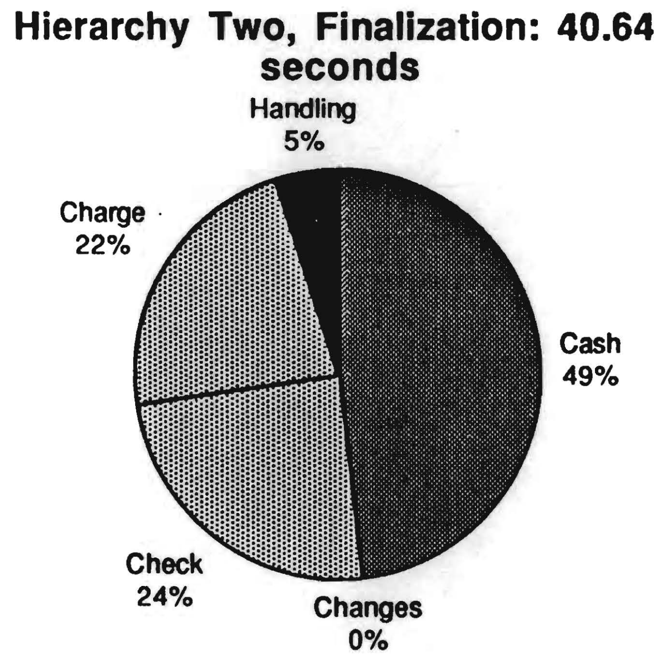




Hierarchy Two: 98.05 seconds

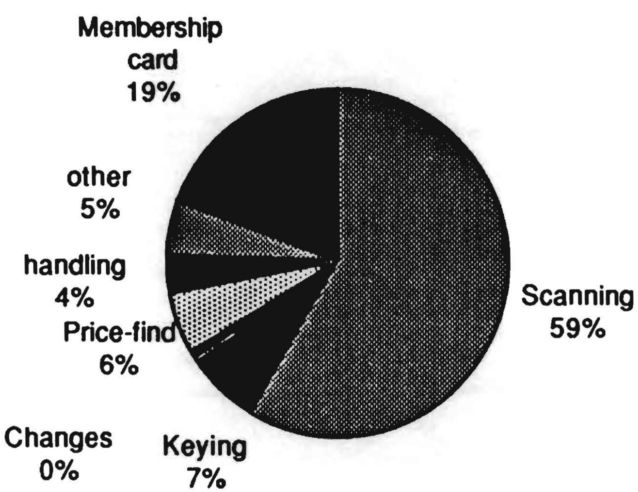
Hierarchy Study - Models



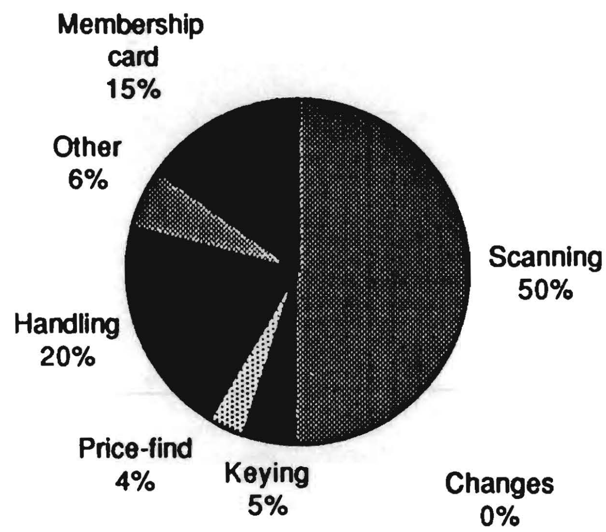


Hierarchy Study - Models

Hierarchy Two, Itemization: 47.85 seconds

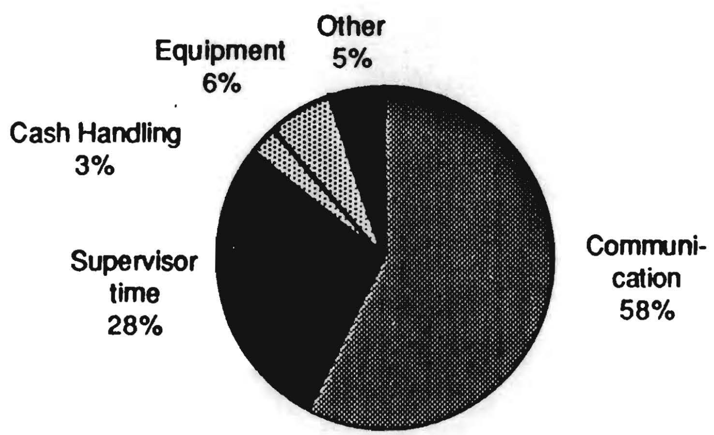


Hierachy Three, Itemization: 50.02 seconds

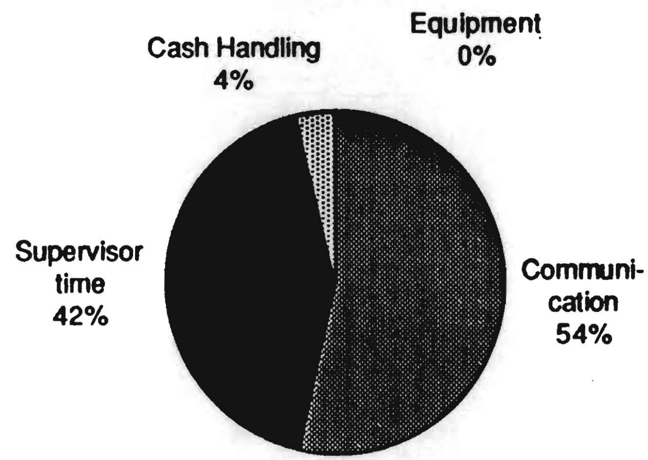


Hierarchy Study - Models

Hierarchy One, Administrative: 10.04 seconds



Hierarchy Three, Administrative: 5.79 seconds



Hierarchy Study - Conclusions

- Possible to structure mnemonics hierarchically
- Possible to describe activities accurately at less detail
- Adequate explanation and training needed so analysts understand what less detailed mnemonics include
- Can reduce analysis time by reducing the number of mnemonics used (e.g. collapse 47 finalization mnemonics to 3 - cash, check, and charge)

Feasibility Study - Conclusions

- Using different points of view, hierarchically organized mnemonics feasible
- Using different points of view provides new descriptions, explanatory power
- Changing level of detail in study can be done accurately, improves analysis speed

Future Tests

- Creating standard mnemonic pool
- Focus on cognitive issues, errors
- Collect categorical data

Further Methodological Expansion

- Goals
- Data Analysis Methods
  - » Field study methods
  - » Analysis focus
  - » Analysis methods
- Applications

Goals

- Develop design guidelines for comprehensive information systems
  - » technology may affect cashier, inventory processes, training needs, skill requirements, customer experience
  - » current methods in human-machine systems may not address all relevant aspects
    - – laboratory oriented
    - – behavior and cognitive orientation
    - – focus on modeling an individual
- Examine methods from other disciplines which may be useful

Data Collection Methods

- Field Study Methods drawn from
  - » Cognitive task, work analysis (Woods, Rasmussen)
  - » Ethnography
  - » Computer supported cooperative work

Analysis Focus

- Communication
  - » between people
  - » between people and equipment
- Use of technological artifacts (e.g. Hutchins, 1990)
- Flow of information
- Effect of context on actions
  - » ethnomethodology (e.g. Suchman, 1987)

Analysis Methods

- Ethnography
- Exploratory Sequential Data Analysis (Sanderson, 1994)
- Interaction Analyses (Jordan and Henderson)
- Grounded Theory (Strauss and Corbin,1990)

Applications

- Study current implementation of technology
- Use during design phase, possibly with follow-up experiments
- Provide specific recommendations, more abstract guidelines, and show how these methods can be used profitably in design

Interviews with Engineers Regarding the Analysis Process

During the month of April, information about the current analysis process was obtained from members of the Human Factors Engineering group and the analysis team at Wright State University. In all, seven engineers and one analyst manager were interviewed. A summary of the comments obtained during the interviews is provided below.

Summary of Interviews
5/1/94

Currently, video analysis geared towards describing fine-grained tasks and producing transaction models is costly and time consuming. Additionally, its focus on generalized models of transactions comprised of physical actions may not be adequate to answer questions about new products, such as Dynakey, where cognitive as well as physical activities play a role in determining usability; in situations other than Point of Sale workstations or where parallel activities occur; and where organizational and social issues may influence the use of a product. Therefore, it is necessary to study the current analysis process in order to improve the efficiency of that process, and to expand the types of information provided by the analysis to answer questions relevant to new products and analysis perspectives.

Summary of interview comments

Description of project types, focus, future analysis needs

Current projects include performing analyses in a wide range of retail environments (grocery stores, department stores, airlines, restaurants), particularly of the point of sale areas in these environments. Analysis goals include improving the productivity and efficiency of the workstation design and equipment in use (e.g. printers, scanners) as well as analyzing software for usability and adherence to good human factors principles, and performing biomechanical analyses. In addition to point of sale locations, some "back office," customer service, and similar work areas (e.g. bank account representative) have been analyzed. Projects also include designing and performing usability tests on new products and equipment, such as scanners, electronic payment equipment and hand-held terminal devices.

Although the current analysis process has been primarily focused on productivity from a time and motion perspective, there is some feeling that this should be expanded in the future to be more comprehensive, covering cognitive aspects and subjective, qualitative descriptions of the videotaped actions. This is particularly necessary in order to analyze different computer interfaces. For instance, more detailed information about system functionality should be captured in terms of the specific key-presses or screen selections made and the information that was presented to the user on the screen. It is also possible that more designed, field experiments can be done to compare different interfaces. Additionally, future analysis should include an expanded focus on the biomechanical or ergonomic aspects of various workplaces. This may require additional camera angles and more detailed analysis (e.g. posture measurements).

Description, components of the current analysis process

Basically, the project process is multi-phased, and ranges from analysis of the customer's workplace, to conceptualizing and prototyping a new design, to implementing and validating that design in the field, depending on the requests of the customer. The scope of the project may range from the design of a workstation to an entire retail system. During the workplace analysis phase, information about tasks, users, and environments is gathered using videotape, observation of possible problems, and by examining forms, manuals, and other workstation material. Transaction models then are developed using motion and time analysis of the videotape. Analysis may also include recording the type and number of comments made to and from customers (e.g., for customer service), or body movements and extensions for a biomechanical focus. Some limited laboratory experiments focusing on a particular equipment parameter may also be performed.

Recommendations made after the transaction models are developed include process improvements such as eliminating steps in the process, changing technology to eliminate or speed process steps, and suggesting training improvements. Typical recommendations improve the process time by ten to as much as twenty percent; however, the customer may not implement all of the changes. Biomechanical analysis can suggest improvements such as using an unload belt instead of unloading from carts to relieve back stress. Laboratory studies can compare the effectiveness of certain equipment, such as showing that certain scanners are faster or require fewer passes, or that certain printers are faster and simpler for the cashiers to use (in terms of the number of hands to operate or to insert a check).

Customer goals and expectations

In general, it seems that customers may have some idea that problems exist with their processes, or want some idea of what is going on at their workplace; however, they do not specify the type of analysis that is done. Typically, customers may only be familiar with cost analysis techniques, and not realize that detailed descriptions of human actions can be performed. However, customers are generally happy with the information they receive, which includes transaction models that provide detailed information about their current operations, comparisons with other retailers, and suggestions for workstation and process improvements. Two important concerns regarding customer expectations were raised. First, since customers do not specifically request transaction models, it is not clear that such a detailed analysis is always necessary. Second, there should be more effort to gather feedback from customers after they have seen the presentation to determine their satisfaction with the study.

Information sources in addition to video tapes

In addition to data gathered from videotaping and observations on location, there are several other sources of information which aid in the analysis of a work situation. For instance, training manuals, participation in cashier training, and performing the cashier tasks all provide information about task procedures and extant sub-tasks. Systems information, such as information regarding the check verification procedure, is also useful (i.e., possibly another procedure would be faster or less expensive when compared to the actual loss due to bad checks). Knowledge of keyboard layout and the particular equipment models is useful for interpreting actions on the videotapes and understanding system functionality. Register tapes, which provide a record of some cashier actions, also help in interpreting the tapes. Electronic data capture of all keyboard/screen inputs and outputs would be useful to this end, but is difficult due to the many different types of hardware and software used.

An important source of information is informal interviews with both store associates and management, which may point out specific problems, likes, and dislikes (from associates who use the equipment) to more global, process concerns voiced by management. These interviews are performed informally, without the use of standard questionnaires, possibly due to the limited time between the start of a project and videotaping of the workplace. It was suggested that a standard library of interview questions, which could be drawn from for each new study, would be useful.

Other useful information gained at the work site includes store reports of the numbers of cash, check, etc. transactions (either from just the filming period or a longer period of time) which can be compared with what was seen on the tapes, and information such as possible biomechanical stressors, measurements of the workplace, and measurements of body movements. Finally, any forms or miscellaneous paperwork used by the cashier, such as a list of phone numbers or of customers who have written bad checks are also informative, since they may point to the need for additional functionality in a system such as Dynakey.

What are the goals and hypotheses of the analysis, and where do these come from?

Analysis goals are process oriented, and geared toward improving efficiency. Specifically, goals (which can be data or client driven), include analyzing movement, equipment (for speed, accuracy), and workstations; modeling transactions; and studying the level of customer service. Other goals include studying deviations from training procedures (resulting from a lack of training, poor procedures, or incorrect manuals), focusing on ergonomic and biomechanical aspects of the workplace, and analyzing the workplace from the perspective of security.

Although analysis goals may be predefined, specific hypotheses and the mnemonics necessary to capture relevant information may not be. The hypotheses that are formed come primarily from experience with similar retailers and observations on site during taping. For instance, with experience, it is possible to predict the problems a retailer might have, or observe that the retailer is not as efficient in some process (e.g. check processing) as a previous customer was. In unfamiliar situations (e.g. a new type of store, customer service rather than POS) it takes more time to come up with relevant questions, and observations made on site may lead to hypotheses about problems (e.g. difficulties storing forms) which can be captured during analysis using specific mnemonics. Discussions with customer management may also suggest problems in areas such as equipment that is difficult to use. Finally, the account team might suggest a focus for the study based on the product they are trying to sell the customer, or the hypotheses might be geared toward supporting a new product that is being designed. An important point is that, although experience and observation are necessary for developing the hypotheses and mnemonics, time pressure (e.g. the inability to make several store visits) may result in repeating what has been done in previous studies rather than coming up with a new set of hypotheses for the new situation. Also, instead of collecting and analyzing a broad range of data, it might be more efficient to come up with goals and hypotheses from a particular perspective (e.g. errors made, efficiency of finalization, etc.) and analyze the data from only that perspective.

What questions are not answered by the current analysis?

Questions that are not currently answered during the analysis fall into several categories. First, it is difficult to analyze interface usability, since detailed information about keystrokes and screen displays is not being captured (at least, not captured effectively enough). For instance, it may be possible to see a person asking for help, but without screen information the particular problem cannot be identified. The information available to the cashier on the screen is not shown, nor can errors caused by incorrect keystrokes be identified.

Also, since the taping focuses on the cashier/workstation, larger issues are being missed. For instance, information such as the number of people waiting in line, or movement through the workplace such as where else in the store a customer or cashier might come from or go to (and the reasons for these movements) cannot be obtained. Similarly, information to support process-oriented questions, such as the reason for store policies, and information flow through the computer system is lacking, or the time to focus on such questions is unavailable. Additionally, because the analysis reduces the data to a transaction model, the sequential nature of the information is eliminated. Variations in task order are missed, and differences in procedures between cashiers and the resulting effect on performance cannot be determined. Conversational analysis of tasks such as customer service is also not often performed, nor is an analysis of the cognitive demands placed on the worker by the task and the equipment. Certain biomechanical questions, which require the use of several cameras, back monitors, and reflective markers are not pursued. It is also difficult to capture parallel activities, such as a cashier who is simultaneously looking at a screen and talking on the phone. Finally, it is difficult to make comparisons between different design iterations of a product, or across projects, since the mnemonics are not held constant.

How are the mnemonics developed? Are they normative or descriptive?

Mnemonics are developed by combining prior experience, mnemonics sets from previous studies and store observation. For instance, experience with previous, similar stores might suggest general problems which will require mnemonics to describe. Depending on the similarity of the new situation to prior projects (e.g. Target and Walmart), sets of mnemonics may be reused. These are expanded and reorganized to reflect tasks, occurrences, and procedures that are specific to the new situation after observation at the site. For instance, if problems storing forms, waiting for supervisors, or checks jamming are observed, mnemonics will be added to capture those occurrences. Even with such observation, it is difficult to capture all situations and the mnemonics often end up similar to those which have been used before. However, in a new situation (e.g. at customer service) there is less reuse of mnemonics from previous studies and engineers rely more on observation and general experience. In some cases, after the data has been analyzed, it is apparent that the mnemonics chosen were not adequate. This highlights the importance of using observations and prior viewing of the videotapes to make hypotheses; and then to choose the mnemonics, essentially the independent variables in the study, accordingly.

In general, the mnemonics tend to be descriptive - the goal is to capture what is actually going on in the store, not what is prescribed in the procedures manuals. However, this varies from engineer to engineer. In some cases, the mnemonics are first based on store policy, and then adapted to reflect actual practices. The extent to which this is been done depends on the amount of observations that have been made, the amount of tape that has been viewed prior to developing the mnemonics, the engineer's experience with a particular situation (with more experience, there is more reliance on an old mnemonic set, which may not be adequately modified), and the time pressure. It was suggested that it would be useful to start out the process in a descriptive manner, creating diagrams and mnemonics that match the existing procedures. In any event, it is important to compare the actual processes to those which are prescribed, in order to identify deviations which may indicate shortcuts, errors, or the need for further training. Examining procedures manuals before the taping and analysis would facilitate this comparison. Models of descriptive and normative tasks procedures, along with models of altered task procedures, can also be compared to predict performance improvements.

What kind of statistical analysis is/should be performed

Analysis performed on the data obtained from the videotapes consists mainly of computing descriptive statistics such as mean times, which are compiled into transaction models. However, other techniques such as non-parametric statistics, ANOVA, MANOVA, regression analysis, or response surface methodologies were mentioned as techniques which might be used in a laboratory experiment, or in a future project. There is also some potential for field experiments, such as varying the mounting angle of equipment, which might require more comparative statistics. Although there were some opinions which favored the increased use of statistical techniques involving significance testing, there are also concerns that, given the amount of data gathered in the field, anything tested might prove statistically but not practically significant. Also, there are questions about the appropriateness of parametric techniques given the large variability in the data, the accuracy of the data analysis, and the fact that most customers do not have the background to understand more complex statistics. Finally, there was a suggestion that currently, several statistical packages are in use and that it would be helpful to have a standardized tool.

Does the analysis provide a feel for the raw data?

The engineers feel for the raw data (i.e. difficulties, inconsistencies with tapes/mnemonics, ambiguous actions vs. neat, processed files) seems to depend on both their own experiences and the quality of the analysis teams. If an engineer has extensive experience with a particular type of store, then he is less likely to spend extensive time reviewing the tapes than if it is a new type of store. However, there was a concern that, without watching the tapes, important information might be missed (e.g. how tasks are actually being performed vs. normative task procedures). Analysis teams can help give a better picture of the data if they are motivated to notice, track and ask questions about unusual events or those which do not fit the mnemonics.

What quality checks are performed on the data?

Quality checks on the analysis are comprised basically of insuring the files are without error, checking the reasonableness of the minimum and maximum times for each task, and insuring that the numbers of task occurrences are internally consistent. For example, the number of transactions should match the number of times the total key was hit. Concerns with data quality include the fact that measuring task times to hundredths of a second may give a false sense of precision, since the analysts cannot react to the tapes with that precision. Also, it is difficult to capture accurate times for concurrent activities, or identify bottlenecks, since times for concurrent activities may not be independent. For instance, a cashier may take longer to bag an item if the printer is slow. In general, performing quality checks and cross referencing questionably timed tasks back to the tapes is time consuming and tedious.

What are the roles of experience and data from videos in making recommendations?

Experience plays a large role in making recommendations to the customer, supplemented with data gathered through observations and video analysis. In cases where an engineer has extensive prior experience, many hypotheses and recommendations are based on knowledge acquired in past projects. Data from the videotapes is used to confirm those intuitions and provide instances of proof to customers. Also, if a project is rushed, without time to test many hypotheses or to extensively explore the data, recommendations are likely to come from experience, with the data used as justification. In fact, there was one comment which suggested that information from the transaction analysis is useful primarily for customers to understand their process rather than to influence recommendations.

Prior experience seems to play two roles. First, it provides clues as to what is likely to cause a problem and therefore, what should be examined more closely. Second, comparisons between performance aspects of the current customer and previous customers can be made. For instance, the check handling procedure can be compared to another retailer who use a particularly good procedure, or the finalization times can be compared to see if the current customer is average or an outlier. There is currently no formal way to store, categorize, or access previous studies, although some information about times for different transaction segments is stored in spreadsheet form. Consistent use of mnemonics across studies (and how they are assigned to transaction segments) is important to be able to make these comparisons.

How much of the data collected and analyzed is used in making recommendations?

The consensus among those interviewed is that more data is collected and analyzed than is applied to making recommendations. First, the tapes may contain much more information than is analyzed in a transaction analysis, such as the time between transactions, influences on cashiers (such as the number of people waiting in line), and more global systems influences. Then, up to half of the data from the transaction analysis may be unnecessary in making recommendations, possibly caused by a lack of up-front planning or appropriate goals. One engineer suggested that if the engineers were performing the analysis, their goals would be modified and become more focused as the analysis went on, and they would tailor the mnemonics to capture only the data relevant to those hypotheses. However, the current procedure does not allow for this iterative analysis.

What information is most useful in making recommendations?

The information that is most relevant from an analysis depends on the goals or focus for that project, and observations about what may be causing problems. For instance, if the focus is on equipment performance, itemization and finalization times are critical, while if the focus is on workstation or organizational issues, miscellaneous activities are more important. In some cases, individual task times and occurrences such as scan times and number of second scan passes are very relevant to the study. In a biomechanical analysis, information about itemization and bagging tasks, as well as information about cashier movement and other ergonomic data (e.g. from stress monitors) is necessary. If the focus is on organization and process improvements, an analysis of paperwork, forms, and interviews or discussions with workers to find out about their jobs, work practices, and interaction with management is useful. Special occurrences and miscellaneous tasks are also important to give the customer a picture of what types of things happen. Although times for different tasks provide information relevant to the goals of the study, it is not clear that forming a complete transaction model is always necessary or informative with respect to making recommendations. Instead, it may serve only to immerse the customer in data.

Comments and suggestions about the analysis process

There were many concerns about the reliability of the data produced by the current analysis. For instance, many task times are out of range which requires time-consuming inspection of the tapes, and the raters do not always agree on the mnemonics they use or when they choose to mark the beginnings and endings of transactions. From the analysts' perspective, there are often problems with poor tape focus or lighting. The camera angle may not include important information, such as a view of the customer, removing some context and making it difficult to identify certain tasks.

There were, however, many suggestions for improving the analysis process. First, the interaction between the teams and the engineers needs to become more iterative. After a small portion of the tapes are analyzed (5%), the engineer should go through the data to make sure it is being analyzed as expected, and the teams should provide information about difficulties such as missing mnemonics and ambiguous actions. Also, the teams should provide some estimate of the time to complete the study (possibly with the help of an estimation tool) and what may be taking too much time, as well as updating the engineer on a weekly basis as to their progress.

Second, there was a consensus that the student teams needed to be more involved in the entire analysis process, including collecting data and performing statistical analysis. They should be briefed on the specific goals of the analysis, and the reason behind certain mnemonics should be explained (e.g. explain why the time to pick up a scan gun is relevant to new equipment design). Similarly, the importance of documenting special occurrences and miscellaneous time in terms of illustrating points to the customer should be explained. Students should also be encouraged to notice and suggest events that might require a second pass analysis. However, this requires better commitment on the part of the teams.

Other suggestions include standardizing mnemonics to reduce training time, having team members specialize in different forms of analysis (e.g. transaction, biomechanical) to encourage expertise, and changing the current procedure to allow time for initial observation to form hypotheses before the data is collected. Finally, although the current analysis appears to be objective, the engineer/analyst is taking a perspective by identifying tasks and assigning mnemonics based on the tapes. It may be useful to choose transactions and have cashiers view the tapes in order to describe what *they* feel is happening during the transaction.

New goals, focus for analysis

Changes in analysis focus include moving away from the current emphasis on the POS workstation. Instead, the analysis could be more product-oriented, providing higher resolution views of equipment so that specific errors can be identified and understood. Also, since the primary role of the transaction model is to describe POS tasks, it is difficult to capture other jobs such as those at services desks: other types of descriptive models should be developed. Movement through the entire work area could also be analyzed.

The focus could also shift from a time and motion analysis to one which includes informational, organizational, and cognitive aspects. For instance, information flow between the cashier, customer, and equipment could be analyzed to help understand and improve the current process (e.g. are there better ways to provide that information? Is that information always necessary, or has it been captured elsewhere in the organization?). Analysis of organizational procedures, such as writing information on a check, can also be analyzed with respect to information flow. It is necessary to ask questions about why an operation is being performed (necessary vs. "standard procedure") rather than just documenting it, although the documentation may provide the information necessary to ask the questions. Finally, a cognitive perspective focusing on how a cashier uses and perceives equipment (i.e. their "mental model") would answer questions about errors made, and reasons for certain actions and procedures (e.g. why they always use a particular scanner window).

Issues in choosing, varying the grain size of the analysis

There are conflicting goals in choosing an appropriate grain size for the analysis. For instance, if the mnemonics are too specific (which may be occurring currently), more information is analyzed than is going to be used, which is not cost effective. Also, at the level of very detailed tasks, the transactions are highly variable, which may not be captured once the data is condensed into a single transaction model. It may be less misleading to create the transaction models from larger task units which are invariant across transactions. However, there are some concerns about analyzing the data at too coarse a level of description. First, to insure proper fidelity, the transactions must be analyzed at a finer level of detail than is needed for modeling. Additionally, a larger grain size might not provide the information needed, (e.g. the components of miscellaneous time), be too vague to support hypotheses (e.g. an error count vs. full transaction model), or prevent the data from being re-analyzed at a later time to answer different questions.

One suggested way to balance these concerns and reduce analysis costs is to analyze the tapes first at a coarser level of detail to provide a general picture of the transactions, and then perform a second-pass analysis to elicit details that are relevant to specific hypotheses. For instance, a first pass might identify types of transactions and process bottlenecks, while the second pass could be used to capture specific task times. If possible, only a subset of the tapes would be analyzed at a fine-grained level to get really detailed information. This may be appropriate for biomechanical studies, where information about movements and extensions could be captured for a subset of the transactions. A larger grain size could also be used to capture subjective and categorical data (e.g. if an error was made, number of scans). There were suggestions that quality would be improved by performing the highly detailed part of the analysis on a second pass, or that miscellaneous time could be described at a second pass. However, there are possible time costs for doing this, and there was one comment that the mnemonics should reflect what is important on the first pass to avoid wasting time.

Choice of an appropriate grain size should depend on the goals of the study, with reduced grain size for more important elements. For instance, if the goal is to evaluate a scanner, than detailed times should only be captured for that part of the transaction. Additionally, categorical data or tallies might be used instead of task times to capture information of interest. If the mere fact that a scan gun is switched between hands is relevant, and not the time that it takes, then only a count should be performed. Although grain size should be variable across studies, changing the mnemonics makes it difficult to compare results between studies.

Issues in generalizing across studies

Generalizing across studies is an important part of the current process, as seen by the role played by experience in generating hypotheses and recommendations. Applying information learned from one project to other projects or designs is an important goal of the analysis. Although some cross-project generalization is done now informally and by individual engineers, it seems important to formalize this procedure to some extent in order to abstract important principles and process standard and apply them across products and studies. Additionally, formally categorizing studies would help engineers develop hypotheses ahead of taping and analysis so the analysis phase can be more tailored.

Creating a standard set of mnemonics may also facilitate comparisons across studies, at the level of itemization/finalization or individual tasks, as well as reduce the learning time for the analysts. However, in order to capture the idiosyncrasies of each environment, specific mnemonics may have to be added for each project. Therefore, comparisons may be easier at a macro- rather than micro-level. Having a standard mnemonic set may also allow menus of mnemonics to be created, so analysts could choose a code from a menu relevant to that part of the transaction, rather than searching for the appropriate mnemonic.

Issues in work sampling

Currently, the choice of taping/analysis times is driven by both ease of access to the work site, and the feeling that if analysis and recommendations are completed for high volume/high stress times, they will be sufficient in lower volume situations. Also, high volume times may result in more efficient cashier performance, more accurately demonstrating actual task times, since customers will typically be waiting in line (although that information is typically not captured/analyzed). It is sometimes possible to verify that the mix of transactions (used in forming the transaction models) found during the taping period is consistent with transaction patterns in general by examining store records; however, these records are not always available, and this increases the workload of the analysis. Representative work sampling seems particularly important for biomechanical analysis, where issues such as length of shift and time on shift may affect movements and cashier fatigue.

Summary

Several broad themes run throughout the interview comments. One main theme involves the importance of experience, or more generally, the reuse of knowledge and documentation in the analysis process. Knowledge from previous studies can be brought to bear in at least four ways. First, it can help in the design of studies and formulation of hypotheses by pointing engineers toward likely problems and possibilities for improvement in the processes that are studied. Second, if sets of general (usability) and specific (to store type) interview questions were compiled, they could be accessed when needed. Third, experience, as well as previous sets of mnemonics, are used to compile mnemonic sets for new studies. Fourth, knowledge of previous customer performance and types of recommendations are used when developing new recommendations.

Clearly, there are significant issues and cautions involved with all of these uses of prior knowledge. For instance, mnemonic sets must be descriptive of the process currently under study, and not simply be a rehash from previous studies. Comparison of results across studies requires consistency in mnemonic use and analysis focus, in addition to similarities between the environments themselves. In fact, relying on experience to excess may lead the engineer into a false sense of security about their knowledge of the intricacies and idiosyncrasies of the workplace at hand. However, given this caveat, it seems worthwhile to attempt to formalize and further support the reuse of knowledge gained and documentation developed for each study. In particular, this will help in disseminating important knowledge (e.g. retailers who are "best in class" for a certain part of the transaction) among engineers, as well as indexing it for reference in future studies. This may also help in the generalization of recommendations for use in the design of new systems, and will make the analysis process itself more efficient and informative by providing easy access to questions and mnemonics.

A second common theme was the importance of tailoring the analysis to answer specific questions or support specific hypotheses. By forming hypotheses before taping, either through observations or experience, the engineer can insure that all relevant information is recorded. Hypotheses should also be formed before the mnemonics are developed and analysis starts, either through experience, observations on site, or viewing the tapes. The grain size of the timed mnemonics, and the use of categorical or subjective mnemonics, should be based on the actual questions that need to be answered, rather than the goal of providing a data intensive, time based transaction model (see below). Alternatively, the data can be analyzed once at a broad grain of analysis to provide a general description of the transactions and activities, and then relevant portions of the tapes can be sampled and analyzed in more detail to answer specific questions. Although this may appear more time consuming, it seems that this approach, particularly when combined with the need to answer questions other than the time tasks take, will be more successful than a brute-force approach.

The third theme concerns the adequacy of the transaction model as the primary analysis tool. This model is very successful at providing a generalized picture of observable activities and identifying process inefficiencies. However, because it is time and motion oriented, focuses on a sales transaction, and condenses information into a single model, it cannot answer all relevant questions. For instance, focusing on a transactions, and the times for individual tasks, may not be appropriate in situations other than POS where the activities comprising a single transaction are spread out over time or when several customers are helped simultaneously (e.g. Sears package pickup). Also, current mnemonics do not explicitly model the parallel activities of the cashier, customer, and equipment. Although some concurrent mnemonics are used, their application is not consistent or comprehensive enough to allow analysis of interactions among the components which may manifest, for example, in bottlenecks in the process. Similarly, it is difficult to capture the parallel activities within a system component such as a cashier who is engaged in more than one task. Sequences of activities, and the variability between cashiers and transactions are also lost.

In addition to the lack of information about parallel activities, focusing primarily on the times of observable activities does not provide information relevant to other concerns. For example, questions about the cognitive demands of a task, the causes of errors, usability of an interface, information flow within an organization, the affect of organizational policies on the task, and the presence of biomechanical stressors cannot be answered by an time and motion analysis. Another problem that is related to the use of one model (rather than the transaction model in particular) is the difficulty comparing actual to normative activities. Without explicit models of both actual and prescribed practice, deviations from procedures and their reasons cannot be understood.

Finally, developing a transaction model requires extensive, time consuming data analysis. This analysis product is driven by the expertise of the engineering team, rather than the requirements of the customer. It is worth considering the value of constructing such models in all situations, particularly when the questions a better answered by other techniques, such as analyzing categorical data, performing usability tests, performing detailed biomechanical analyses, or analyzing information use.

The fourth and final theme involves suggested improvements to the analysis process itself. First, there should be more involvement with the analysis teams. Analysis teams and engineers should interact early in the study to insure that the data is being analyzed as expected, that the mnemonics provided are adequately and accurately capturing the tasks of interest, and that particularly time consuming analyses are worth the time cost. Teams should provide more information regarding special occurrences and possibilities for second-pass analyses, be briefed on the study hypotheses and importance of particular mnemonics, and should be integrated into the data collection and statistical analyses phases of the studies.

Second, the process should be more iterative, and have the flexibility to change throughout the data analysis process. Time should be allotted for the development of hypotheses before data collection, and the fine-tuning of hypotheses and mnemonics after analysis has begun. The procedure should be sensitive to the information provided by the analysis teams regarding the actual content of the raw data. For instance, it should be possible to change mnemonics, or the grain size of portions of the analysis, as interesting activities emerge from the tapes, or other segments are judged less informative. It would also be useful to add the potential for a second-pass analysis to answer new questions that arise during the study, or to study some activities in more detail.

Finally, an important addition to the current process would be the use of retrospective verbal protocols of the cashiers. Having cashiers view and explain taped transactions may shed light on the reasons behind certain actions, the information being used from a particular screen display, and the cause of errors, in addition to confirming analysts' interpretations of the events.

Requirements for an analysis tool

Given the factors discussed above, a new analysis tool which combines videotape control, viewing, and computerized coding and analysis in order to improve the efficiency of the analysis process has several requirements. First, it should support the reuse of information from study to study, including likely problems, interview questions, and results and recommendations. An additional benefit of keeping track of previous studies is that by comparing certain parameters (e.g. number of transactions, number of mnemonics, type of store) a better estimate of the time for the video analysis might be obtained. Also, the tool should allow for the creation of a standard mnemonic set, including mnemonics at different levels of detail, to facilitate comparisons between studies. If the tool supported the organization of the mnemonics into a hierarchical menu structure, it would simplify analysts' choices, and improve data quality.

The tool should also support parallelism, in two ways. First, it should support and make explicit the description of concurrent, parallel activity streams throughout the analysis. Second, it should support parallel descriptions of the same activity, each in a language of description tailored to a specific, different goal. A tool should also support flexibility and iterative changes to the analysis. For instance, it be possible for analysts to replace previously coded mnemonics with different codes, annotate tasks, and flag certain tasks for expansion into a more detailed description. Also, the tool should allow task descriptions to be viewed at varying levels of detail; this would be facilitated by the inclusion of support for a hierarchical mnemonic structure. For example, a transaction could be described at the itemization/finalization level of detail, with perhaps only the scanning times listed in detail.

An analysis tool should also provide on-line quality checks while the analysis is being completed to improve quality and reduce tedious error checking. Most quality problems involve out of range times or missing tasks, which could be flagged at the time of analysis if the tool could compare the analyzed task time with a stored acceptable range, or check that all parts of a transaction are noted. However, given the uncertain nature of the tasks that may be observed, it should always be up to the analyst to either correct the flagged item, or leave it unchanged (possibly with some explanatory notion).

A final necessary feature is the support of statistical procedures, including more sophisticated techniques such as MANOVA and non-parametric tests, or at least the ability to transfer data to such a package with ease.

Assessment of MacShapa

On October 31 - November 1, Amy Bisantz traveled to the University of Illinois at Urbana-Champaign with Karen Wilson, to attend a two day workshop to learn about the video and data analysis tool MacShapa, and to assess its suitability for our analysis requirements.

Expanding Design Methodologies for Human-Machine Systems Engineering

The following literature review describes field study methods and issues regarding these methods which may be appropriate for detailed study of retail environments. It was written by Amy Bisantz to be included in a dissertation proposal.

Summary

Developing information systems which are usable across a work organization requires the evaluation of many aspects of the work and organization, including actual work practices and communication patterns. However, the majority of research programs have focused on studying system usability in the laboratory, or describing and modeling cognitive aspects of individual users in order to provide guidance for designing technology which better supports cognitive capabilities. In the following literature review, it is proposed that it may be profitable to expand these efforts, combining traditional methods with ethnographic and other methods of study which attempt to paint a comprehensive picture of a culture (in this case, a workplace culture) through detailed field study. These methods may help expose factors, in addition to cognitive concerns, which might also affect the successful use of new technology, such as formal and informal communication patterns or organizational pressures. The application of these methods to the design of retail technologies is discussed.

Expanding Design Methodologies for Human-Machine Systems Engineering

Introduction

Designing comprehensive information systems which involve many parts of a work organization pose many design challenges, only some of which have been addressed by current methods in human-machine systems engineering. For instance, in a retail environment, introducing new systems can affect not only the cashier at the point of sale, but also changes the way inventory is tracked, returns are processed, and pricing is done (e.g. using bar codes vs. numeric pricing). In turn, these changes can affect training needs, job requirements, supervisor involvement, and even the experience and involvement of the customer in the sale. Design and productivity oriented analyses are currently being performed in retail environments, but these typically focus on the interaction of the cashier with the terminal at the point of sale, and do not always extend to include the interaction of the entire retail organization with the information system. Also, the studies focus on the overt behavior of the cashier and are less concerned with cognitive aspects of the task, information flow throughout the organization, and communication patterns and social interaction among members of the organization and also between employees and customers.

Describing these aspects of a retail environment will provide useful information for the design of such systems. However, it is necessary to find and adapt techniques for studying such aspects of an environment in a way that is rigorous and detailed enough to provide concrete, specific information which will be useful in design.

Literature Review: Expanding Methodologies

In order to identify appropriate concerns in the study of the interaction of technical systems and organization, and to identify useful methodologies for their study, research in several diverse areas will be reviewed. First, the need for expanding methods current accepted in human and usability oriented engineering disciplines will be discussed, as well as possible aspects of study in the area of designing technological systems for work environments. Then, methods of study and approaches to these issues will be discussed, and applications of these methods will be provided. Finally, the implication for analysis of retail environments and design of technology suitable for these environments is presented.

Human factors engineers have traditionally been concerned with designing technology that is usable from a physical and cognitive perspective. The focus has expanded from studying one person using a single display to the study of humans interacting with more complex systems, although many experiments are still performed in the controlled and simplified environment of the laboratory.

It has been suggested that this approach, including research in cognitive engineering and experiments in human-computer interaction, is not sufficient for the successful design of new technology (Adler and Winograd, 1992; Button, 1993; Heath and Luff, 1993; Hughes, Randall, and Shapiro, 1992; Monk, Nardi, Gilbert, Mantei, and McCarthy, 1993) since it may miss many aspects of the use of technological artifacts in real work situations. In particular, studying the usability of interfaces typically ignores the fact that the goal of operators is not to work with interfaces or technology, but rather to perform tasks and solve problems that do not concern the interface itself. "Natural life environments cannot be reduced to interfaces, even interfaces are the only windows between the operator and the environment (Montmollin, 1991)." Also, as noted by Monk et al. (1993), experimental methods are geared towards studying individual behavior and are not as suitable for studying group activities. Instead, methods must be used which can identify aspects of a work domain, such as organizational issues and communication patterns, which are relevant to the design of technology for those environments. For instance, Heath and Luff (1991) describe the need to understand the way social organization skills allow people to recognize what other are doing in tasks that move beyond individuals working with a system to a group of people interaction and coordinating many tasks and tools. One way to inform such efforts is through the detailed study of current environments where new technology has been implemented in order to identify factors which have impacted its successful use. Such factors could then be considered in a new design.

Montmollin (1991) also discusses the contrast between laboratory and real world environments, noting that in laboratory experiments complexity is avoided to provide control, while in field experiments complexity is respected and is a focus of study. Also, he describes the differences in time scale between the two situations: experiments occur in minutes or hours, while actual work activities can extend over weeks and years. He claims that a laboratory study and subsequent modeling result only in an analysis of the experimental situations, which is not equivalent to a real work situation. He feels it is impossible to reduce complex activities to general characteristics which apply across work situations and therefore be abstracted for testing in an experiment, and that operators cannot adequately be modeled as humans with simple, decomposable characteristics. Montmollin does suggest full scale simulation as an acceptable compromise to studying the actual work situation.

This progression in methodologies can be considered a natural and necessary step in the field of human-machine systems engineering, which has evolved along one dimension from the study of human physical capabilities to incorporating cognitive issues in the design of work. In terms of complexity, the focus has shifted from experiments which study a single person performing one task or using one display to observation of an operator performing more integrated tasks such as fault diagnosis using a range of information sources in a complex environment. Additionally, there has been research done which studied groups of individuals in the areas of collaborative work and cooperative decision making from the perspective of providing aids for small work groups, or enhancing communication between individuals in different locations or who work asynchronously (e.g. Bikson and Eveland, 1990; Heath and Luff, 1993). Therefore, a logical step is to continue this expansion to include the study of groups of individuals working with sets of artifacts, throughout an organization, and study how their collective work can best be supported.

The important question is what methodologies will best support this study and provide concrete information to aid design. In particular, it may be necessary to supplement top-down approaches to providing design information which seek to model operators and systems with a bottom-up approach that supports design directly from the data. Montmollin (1991) conducted a review of studies regarding people interacting with complex technologies, and found that a large number of studies were not empirical, but used normative models of operators. These models were developed by studying the system and tasks, interviewing operators, and looking at records of performance; however, the models were seldom validated empirically. Occasionally, the models were compared to human behavior, but in these cases Montmollin notes that it was the ***human*** that was being tested against the normative model rather than the model.

There have been several research methodologies and studies which have expanded beyond laboratory experiments in order to study technology as it is used in practice. For example, Woods (1993) presents methods for studying cognitive tasks such as decision making and problem solving in complex, real world situations rather than in simplified laboratory environments, in order to obtain results which are valid in the real world and can be generalized to other situations. These methods include "process tracing methods" which provide descriptions of events as they occur, including the information used and actions taken by participants, in order to make inferences about internal cognitive processes such as knowledge activation and information use. For instance, the verbalizations of participants can be analyzed to look for information which reflects underlying cognitive processes. Behavioral protocols can also be developed from field studies, using information gathered through direct observation, records of information accessed and actions taken, traces of system state, and records of verbal or other kinds of communication. These protocols provide a record of events in terms of the information used, situations assessed, knowledge activated, and participant actions and intentions: in short, they trace behavioral and inferred cognitive activities in a real work situation.

This focus on describing participants' cognitive activities is emphasized in the design oriented methodologies of cognitive work or task analysis. For example, Roth and Woods (1988) present a methodology which attempts to describe the information accessed, knowledge activated, and strategies used by operators in a complex system in order to better use the capabilities of technology to assist operator activities. Similarly, Rasmussen (1986) suggests a method of cognitive task analysis for identifying the cognitive activities of operators in complex systems in order to support the problem solving and decision making activities of such operators, by analyzing the system, decision sequences, and possible operator strategies. Rasmussen (1994) and others (Vicente and Rasmussen, 1992, Montmollin, 1991) have made the important point that, because situation will arise that cannot be anticipated by system designers, some type of evaluation beyond an enumeration of normative procedures must be completed to effectively support operators in complex systems. Rasmussen (1994) describes a methodology for describing the work domain in terms of its functional and physical aspects and the constraints these provide on operator actions, so that all possible actions can be supported. These theories are echoed by Montmollin (1991) who suggests that traditional methods of task analysis are not effective because they assume (incorrectly) that environments are predictable, when instead studies which try to model actual operator activities show that their behavior does not conform to the prescribed tasks. Instead, operators use their knowledge of systems to perform tasks, within the constraints of the physical process itself and higher level, organizational policies.

To this point, then, the primary methodologies described for studying humans and technology in the workplace have focused on describing, modeling, and supporting the cognitive tasks of individuals. An important addition to this research includes a shift from the focus on the individual to groups of people acting in a goal oriented way. For instance, Reason (1987) claims that a focus on an individuals' decision making or planning behavior is inadequate, since in reality plans are developed by groups of individuals. His concern is since planning is better viewed as a satisficing heuristic rather than a optimizing procedure, it is important to understand how errors due to the heuristic might be exaggerated by propagating through the organization. Montmollin (1991) also notes that the workplace and an isolated operator have been the focus of research, rather than models of collective activities. What research has been done regarding groups has focused on supporting normative communication patterns and task allocation between individuals, and have not considered interactions between workers in actual work settings. Hutchins (1990) also stresses the need to study the communication and coordination among workers, stating that "people are the connecting tissue that hold the technology together - the devices communicate through the people."

A shift in focus from individual workers to collective activity brings with it a natural expansion of interest from cognitive tasks to a more complete, multifaceted description of the workplace (e.g. Quintanilla, 1987; Bentley et al., 1992; Luff and Heath, 1993). For instance, Montmollin (1991) notes that there has been more recent research which has focused on interaction and communication in the workplace. Writing from a sociological rather than cognitive viewpoint on the introduction of new technology into the workplace, Button and Harper (1993) stress that it is necessary for designers to understand technology in context. When new technology is used to computerize an existing process, it is being placed into an organization with existing social and work practices, and can disrupt existing practices by creating new interaction demands, or requiring changes in practice. These changes may result in practices which are inadequate to support the necessary work, if the underlying reasons for the initial practices were not understood and accommodated by the technology's designers. Ultimately, this may force workers to work around or ignore the new technology. Because work practices are situated within the context of an organization, Button and Harper feel that studying both the organization and the tasks, activities, and communication patterns in the workplace, as well as the functionality of the new technology, is necessary to provide useful design information.

These concerns are echoed by Adler and Winograd (1992), who claim that a new type of equipment or software must be assessed, not only in terms of its technical merit, but on how it can fit into users' work practices, providing benefit to users in completing their work without hindering them. Adler and Winograd (1992) and Adler (1992) also tie the organizational and management influence on the design of new technology, and the interaction between people, the organization, and the technology to its ultimate success in the work environment. They claim that when organizational pressures force technology to supplant rather than support the skills of workers, eliminating rather than fitting in with work practices, it is likely that the new technology will be resented by, and not useful to, workers who have been relieved of their job responsibilities. Adler claims it is a myth that successful new technology allows fewer workers with fewer skills to do narrower jobs. Instead, new technology will be more successful when it is used by highly skilled employees, and when the technology augments the worker's skills, allowing them to deal successfully with unexpected events and solve problems that they would not have otherwise. Both changes in work content and organizational structure must be understood in order to successfully change to new technology.

Several other researchers have noted the importance of accounting for skill requirements changes in manufacturing operations (e.g. circuit board assembly, metal cutting) which shifted from hands-on manufacturing to more automated, computer controlled operations. These studies found that, instead of requiring manual skill to detect and solve problems, the new technology required workers to monitor displays and program equipment. Hirschorn and Mokray (1992) investigated changes in what made people feel competent and in what skills were required when work changed from making a product by hand to watching it being made through an interface. They suggested that, because of these changes, workers needed more explicit knowledge about their jobs, rather than the tacit knowledge they had previously used in order to remain competent. Likewise, Kern and Schumann (1992) described how systems where operators monitor processes require the operators to have theoretical knowledge about the processes, as well as experiential knowledge and heuristics in how to cover for inadequacies of the technological system. Attewell (1992) described how certain elements of skills may remain important while other aspects become irrelevant, as with operators who, after their metal cutting equipment became computer controlled, no longer could constantly feel the vibration of the machinery, but instead became attuned to the sound of the equipment in order to make quality judgments. In any case, these changes in skill requirements must be understood and accounted for when new technology is introduced.

Kern and Schumann (1992) also describe some of the ways new technology can affect work organization, presenting two models of such effects. In the first, a *technocratic* model, traditional distinctions such as those between direct and indirect labor are preserved. Technology is used to provide automation and expert systems as solutions to unanticipated events and to reduce risk, and maintenance and planning are provided by specialists. However, because regular operators lack critical skills, these specialists spend much of their time running the process and dealing with minor problems. In contrast, in an *integrated* model technology is used to integrate maintenance, quality control, and planning functions into production work. Although more operator training is required, Kern and Schumann believe the increase in responsibility will attract more motivated employees.

To account for such considerations in design, it is necessary to study the work environments with methods that are sensitive to the correct set of variables. In particular, it may be useful to provide a description of existing work practices, including social interactions and considerations such as communications between individuals and organizational pressures. For instance, Quintanilla (1987) discusses a four level approach to studying social factors relating to new technologies and human error. The first level of description, which focuses on the individual, encompasses traditional research in human-machine interaction which is based on theories derived from a general psychological framework. Since this research has typically been biased toward the individual worker, Quintanilla has proposed that a second level of description should be based in social psychological theory, and should focus on work groups and their interaction with technical systems. This level would capture how social processes play a role in the operation of systems, particularly on the presence or absence of errors. For instance, there may be operational norms developed and reinforced by the group (e.g. ignoring a certain alarm, disabling equipment safety features for convenience) which are contrary to the designers' intentions.

The third and fourth levels describe operators' interactions with technology from an organization and societal perspective, respectively. For example, new technology may provide flexibility within an organization such as a reduction in strict job classifications due to increased access to information, or it may impose new strictures on employees if they are forced to use new equipment or are subjected to electronic monitoring. Employee input and changes in organizational structures (e.g. union organization) may promote flexibility. From a societal perspective, Quintanilla sees a desire for work that is self regulated, with some freedom of action left to operators. Therefore, technology should be assessed at this level in terms of the extent to which it supports discretionary action, such as multiple strategies for problem solving.

Work as a situated activity

Suchman's theories of action and work activities (Suchman, 1987; Suchman and Trigg, 1991), and methods for studying humans interacting with technology are useful in understanding work practices and their importance in design. Suchman's primary theory is that action takes place in the context of a particular social and physical environment; and in particular, work activities occur in a specific social situation. Such actions are context sensitive and therefore are dependent on specific contextual circumstances which cannot be fully anticipated. Understanding such circumstances is crucial to the understanding of action. This is in contrast to what Suchman calls the "cognivist" view of plans as a formal structures, composed a priori, which control sequences of detailed, explicit actions to accomplish a known goal. This account of action is inadequate, since plans are necessarily vague in order to accommodate the unanticipated, contextual nature of environmental circumstances. Suchman (1987) states that "our actions, while systematic, are never planned in the strong sense that cognitive science would have it. Rather, plans are best viewed as a weak resource for what is primarily an "ad hoc" activity (p. # needed)." It would be impossible to plan action at the requisite level of detail for execution of action. For instance, there are many examples of intentional activity which could not be planned in detail, such as braking a car to avoid an accident. Instead, high level, vague goals or intentions (such as remaining safe) serve to guide the activity which occurs in response to specific situations. These notions support the methods proposed by Rasmussen and other described earlier, which attempt to support operator activities not by modeling set procedures, but by understanding the envelope of goals and environmental aspects which constrain their activities. Furthermore, instead of a representation which produces action, Suchman claims that plans can be understood as result of reasoning about and providing an account action. This account provides a reconstruction of the activity which tends to emphasizes the rational progression of actions and remove the situated aspects of the activity, leading to the incorrect interpretation that a rational plan guided action.

Thus, the common characterization of human activities as following predetermined plans is inadequate: plans do not determine nor account for the actions that occur. Therefore, a representation of action as a formal plan is not a good basis for understanding action. This distinction is important in design since interactive technologies are designed to accommodate some underlying theory of human action, whether or not that theory is made explicit. It would therefore be a mistake to design technology which embodies a planning theory of action; instead, designs should accommodate actions as they are understood in the work context.

Approaches and Methods

To take these theories into account, a research focus should incorporate information about the way technological products, or artifacts, are used *in practice,* in a work situation, into the design of such artifacts. In particular, the organizational structure, communication between individuals, sources of information, and actual work practices all affect and are affected by the implementation of new technology. Determining these effects in order to enhance those that are beneficial and attenuate those that are harmful should be done to the extent possible during the design and test phase to insure that the change induced by the technology is positive. This determination should be accomplished through direct observation of work situations rather than experimental laboratory studies. The result of this focus is an approach to design that is grounded in actual work practices, driven by data rather than predetermined theories, is useful given the skill level of the employees, and which has a goal of designing new technology which fits seamlessly into the existing workplace rather than denying or upsetting existing practice.

In order to accomplish this task, the work place, activities, and use of technology must be analyzed. Methods drawn from sociology and anthropology such as ethnographic observation, interaction analysis, and grounded theory have been used in other studies to capture extensive information about workplaces, activities, processes, and communication between individuals. Also, descriptive frameworks such as ethnomethodology and situated action may be useful in understanding observational data.

Ethnography is a descriptive methodology that seeks to provide an understanding and coherent description of activities in a particular environment or culture. Agar (1986) describes an ethnography as the product of the interaction between the group being studies, the traditions and experiences of the ethnographer, and the audience the account is meant for. In contrast to more traditional sociological study which attempts to test hypotheses by measuring variables of interest, ethnography tries to answer the question of what is going on even without a pre-determined theory. In this way, as described by Bentley et al. (1992) ethnographers typically do not have preexisting theories which affect the type of information they collect, preferring not to judge the potential value of information. As Jordan and Henderson (in press) discuss, conclusions and generalizations are drawn from records of activities rather than by using structured, normative theories to filter and interpret data. Theories and generalizations are derived by studying specific, naturally occurring activities rather than by manipulating and measuring events.

However, ethnography is not atheoretical. Agar (1986) describes the process of ethnography as one of resolving breakdowns in understanding and iterating through explanations of action until a coherent set of theories is found which applies across the activities of interest. Breakdowns occur when there are differences between the ethnographer's understanding of the situation. This provides an opportunity for new understanding on the part of the ethnographer. . Breakdowns are resolved when the ethnographer's understanding is altered and the group's actions can be interpreted as part of a coherent plan. Agar discusses this change as a shift in or creation of new schemas (in the cognitive sense) which the ethnographer uses to make sense of a situation. Therefore, ethnographies are affected by theories; in particular, the goals and knowledge of the ethnographer affects which actions cause breakdowns in understanding and thus what needs to be explained, to understand them. Also, the way the ethnographer parses the activities into segments of interest, and chooses the language used to describe the breakdowns are also dependent on the ethnographer's theories about the world.

There are several defining characteristics of ethnographic study. First, data is typically gathered through participant observation rather than through experimentation or manipulation. According to Monk et al. (1993), the observer often attempts to be as unobtrusive as possible, and "adopts the position of uninformed outsider whose job is to understand as much as possible about the "natives" from their own point of view." For instance, in order to study behavior in a natural setting without manipulating the events, Heath and Luff (1993) left video and audio recording equipment set up over several weeks. This was particularly unobtrusive, since the subject of interest was workers' use of video and audio mediated communication technology.

Second, in order to understand these activities within their context, ethnographic studies typically involve a very detailed record of the environment of study and the activities that occur within that environment. For instance, in a study of how ideas of time structure the activities of research physicists, Traweek provides many pages of description of the scientists and their environment, down to the scientists' personalities and educational levels, their dress, the placement and cost of equipment, and the disorder in the yard outside the accelerator building, in order to paint a picture of the physical environment which provides a context for the description and interpretation of action. Also, as Suchman (1987) describes, ethnographic studies should attempt to identify aspects of the work that participants see as important or rely on, even if those aspects are so familiar and ingrained as to be transparent to those involved. To this end, Orlikowski (1992) suggests that observation before, during, and immediately after the implementation of a new type of equipment or software allows a description of the process of change caused by the new technology. In this way, the impact of the new technology can be assessed by observers or the users themselves before it becomes part of normal work practices. (Elm and woods paper cite here, operating room monitors). This point is also made by Koenig (1988) in a study of new medical technologies (see discussion below).

Third, in order to capture such data, researchers employ techniques which include the use of observation over time periods ranging from several days to months, interviews , video and audio tapes, and a cataloging of events, tools, information sources, and movement through the workplace. Interviews may vary from structured and unstructured, and typically include a set of open-ended questions that are brought up in a conversational style rather than in a fixed order (e.g. Nardi and Miller, 1990). Monk et al. (1993) describe a range of foci for ethnographic observation, including descriptions of the social rituals, institutions, and artifacts that are used in a situation. Videotaping in particular is considered valuable by some researchers, because it provides a record of actions that is relatively independent of the observer or analyst (Suchman, 1987), and because it is a record of activity rather than an account of it (Jordan and Henderson, in press). Also, as Jordan and Henderson point out, videotaping and subsequent review allow analysis of the actions of more than one person with details that a single not-taking observer would not be able to capture. However, decisions regarding camera placement and movement, as well as choices made in filtering the enormous quantity of data for subsequent analysis result in data which is not completely unbiased. The bias of the observer is replaced by the bias of the equipment, but which can at least be (if camera position is constant) a consistent bias. Also, videotape, though a rich data source, cannot capture all aspects of a situation: temperature and odors cannot be captured, and color and sound information may not be accurate or complete. (Jordan and Henderson, 1993).

Finally, this methodology is characteristically iterative in order to provide interesting generalizations which remain grounded in data. Following a period of observation, theories about the workplace activities are formed from the data, more observations are gathered to verify or complete the theory, and the theory is abstracted and modified while still remaining true to the data. This cycle is continued until the researcher is satisfied that data captured provides a complete picture of the work situation (e.g. Minneman, 1991).

Monk et al. (1993) present a critical discussion which compares ethnographic methods to more traditional experimental techniques, in order to identify methods suited for studying computer mediated communication. They point out that ethnography provides a description of communication in terms of its context, while psychological methods would interpret the sane data as information transfer with respect to some goal, and attempt to control the situations and context in order to test data for statistical significance. From the ethnographic point of view, it is meaningless to collect data in an artificial context rather than from an actual work situation. Laboratory experiments are not representative of the real world because they do not control nor describe all relevant variables, do not provide a description of subjects thoughts and beliefs about the tasks, and are not representative of the real world because the tasks used are often artificial and unrealistically time-constrained. The literal translation of ethnography, to "write culture," reveals its goal, and from this perspective ethnographers will always provide some information of interest. However, the important question from a design standpoint is if the information described is general and practical enough to be used to guide design. From an experimental point of view, it is not possible for ethnographers to generalize beyond the sample case that is described: the study of one group or situation may be less representative than a laboratory simulation. Instead, a compromise may be to use experimental techniques in applies settings, allowing for the measurement of subject variability and subsequent generalization that current ethnographic studies lack.

In addition to ethnographic techniques, an ethnomethodological approach to studying interaction may be valuable. Ethnomethodology treats normal activities, circumstances, and practices as the topics for empirical study. According to Garfinkel (1967), ethnomethodology refers to "the investigation of the rational properties of indexical expressions and other rational actions as contingent ongoing accomplishments of organized artful practices of everyday life (p. 11)." That is, ethnomethodology seeks to understand how people accomplish everyday actions (e.g. conversation, work activities); and in particular, the way specific situational contexts and shared understanding among participants contributes to that accomplishment. As Livingston ((1987) describes, ethnomethodology is the "study of peoples' methods" for getting tasks done, and gives as an example the methods groups of people use to cross a street without colliding. Ethnomethodology is also interested in how people themselves think about these methods, and how these accounts are tied to the activities they are describing. Livingston (1987) feels the adequacy of an ethnomethodological study can be measured by the analyst's success at describing these links. In contrast to other sociological methodologies which consider sociological facts as fundamentals independent of their instantiation in human activity, ethnomethodology considers social practices as deriving from and embedded in the ongoing accomplishment of daily life, and considers how such activities are even possible (Garfinkel, 1967). These activities proceed because of practical sociological reasoning on the part of participants, and practical methods for making actions and knowledge mutually understood.

Similarly, Suchman (1987) describes the ethnomethodological approach as one which focuses on the study of everyday social activity, rather than describing actual practices only in terms of their deviation from normative models of social practice. Suchman's theories of situated action are an example of the application of this approach. Instead of being based on social norms or cognitive schemas, action is explained in terms of the interaction of people with each other and the environment. Jordan and Henderson (in press) also support an ethnomethodological approach, claiming that knowledge and action are social in nature, and that expert knowledge is not cognitive in nature but exists in the interactions among people. Therefore, they feel that the appropriate data to collect are not traces of cognitive activities, but details of naturally occurring social interaction. In this way, the shift towards using ethnomethodological approaches to understanding social situations parallels the shift towards describing naturalistic rather than normative decision-making behavior (e.g. Klein, 1993, Woods, 1993).

Jordan and Henderson (in press) describe a methodology, *Interaction Analysis*, for analyzing videotaped data which can provide data for ethnomethodological and conversation analyses. This methodology, which is used to analyze interactions among people and between people and objects, depends on ethnographic techniques in that the videotaped data is typically gathered as unobtrusively as possible, through participant observation. Jordan and Henderson consider artifacts and technologies to define possibilities and probabilities for actions in an environments, and use Interaction Analysis to identify regularities in how people and technological resources interact.

The method involves replaying videotapes for a group of researchers who stop the tape to discuss actions of interest for a brief period of time. The audiotapes of these sessions, along with other data sources such as transcriptions of conversations or computer activities, are then analyzed to look for regularities in the actions on the tape and to point the way for more focused ethnographic studies. Jordan and Henderson feel this method provides several advantages, including reducing observer bias since biases are discussed by the group of researchers viewing the tape, and keeping theories of action grounded in the data, since the tape can only be stopped for a limited amount of time, reducing ungrounded discussion. They also claim that analysts do not speculate on cognitive activities that are not supported by the tape, but may use actions to support a cognitive interpretation., For example, a clip showing a person stretching to write in the top corner of the white board may be used as evidence that he has a plan to write more.

Jordan and Henderson do not use a pre-determined scheme for describing actions; however, they do have methods for dividing the scene into dimensions of interest. Data that is typically captured form the tapes include chunks of activities; transitions between activities which are indicated by such things as speech, movements, and introduction of new people or objects; and movements through space. Jordan and Henderson suggest a set of dimensions for analysis of technology use, including who uses the technology, how it is distributed in space and to individuals, its movement through space and among people, how it enters and leaves the scene, and how it structures interaction. They feel that their methodology is appropriate for studying the introduction of new technology since it attempts to characterize the types of regularities in action that are supported or caused by technology, and thus can be used to understand how this changes are new artifacts are introduced.

Sanderson and Fisher (1994) present a methodology for analyzing observation data, *exploratory sequential data analysis*, which emphasized preserving the temporal nature of data and discovering sequential relationships within the data. They feel the investigation of this sequential nature is necessary for the study of human-computer interaction, because interaction with systems and tools unfolds over time. Also, due to the complexity and the behavioral, cognitive, and social aspects of this interaction, an observational rather than laboratory approach is necessary. Sanderson and Fisher (1994) provide a review of techniques taken from behavioral, cognitive, and social traditions which focus on data analysis and in some cases the sequential nature of that data. For example, they discuss inferential statistics, cognitive modeling, and interaction analysis and ethnographic techniques. They also discuss several important features of exploratory sequential data analysis, including chunking data into meaningful segments, coding and commenting on actions, and creating links between related segments of the data.

A grounded theory approach is another qualitative research technique which may be valuable when conducting field or case studies. As described by Hirschorn and Mokray (1992), in grounded theory, facts do not test prior theories but instead contribute to the development of a theory. The emergent theory then provides some clarification of and generalization from the initial data. Strauss and Corbin (1990) describe grounded theory as a process of inductively developing theory through the qualitative analysis of data, in order to make sense of the material collected, and discuss the difficulty of creating a theoretical interpretation while still remained true to the collected data. Strauss and Corbin stress that the grounded theory approach relies on qualitative *analysis* of data rather than mathematical or statistical analysis of qualitative data to provide theoretical description.

This analysis is comprised of systematic, iterative procedures for describing and coding collected data which become more focused as the analysis process continues. Data are provided with conceptual labels and then grouped into progressively abstract categories. The analysis reveals theoretical themes such as dependence on context, causal processes, strategies, processes of linked strategies, and preconditions for actions which are combined to form models of the phenomena of interest. These models, or theoretical interpretations, are continually compared against extant data to insure that they provide a reliable and consistent description of the data (Strauss and Corbin, 1990). Hirschorn and Mokray (1992) provide an example of the use of grounded theory in their case study of workplace competence in an environment of changing technology. They conducted in-depth interviews with employees who had witnessed the changes, had those interviewed review the notes to insure their accuracy, analyzed the interviews for general themes and then formed more specific hypotheses to aid in understanding the patterns of responses.

In addition to the sociological and anthropological methods described above, there are other techniques which may be appropriate for studying interaction with technology. For example, Watts (1994) studied navigation through pages of a computer spreadsheet using a combination of methodologies. First, she identified difficulties users had in navigation, and the compensatory strategies they used to successfully navigate through large spreadsheets, by observing individuals in their actual work environments, interacting with the spreadsheets they normally used. She then extracted certain navigation cues from the field observations and developed field experiments to test their importance in a more controlled situation. These experiments differed from controlled laboratory experiments in that the tasks were open ended: subjects were not instructed to use any particular function but instead performed tasks in the presence or absence of certain navigation aids (e.g. landmarks such as column and table headings). An important facet to this research is that both the observations and field experiments were informed by previously developed theories of navigation in a computer medium. Observations of difficulties, strategies, and navigation cues could therefore be categorized and tested in terms of those theory, and provided evidence which supported theoretical predictions.

The presense of such a framework allows the observational stage of the analysis to be more focused and tailored to the particular study goals. However, these methods are in contrast to the principles of ethnographic study, in which data is collected without a particular scheme in order to insure that any theories or generalizations are derived bottom-up from the data, and that the set of data collected does not bias the analysis toward one particular theory.

Methodologies from conversational analysis may also be necessary to document and understand interactions in a work domain. For instance, Erickson (1982) discusses two important problems in conversation organization: topical cohesion and floor management. Topical cohesion refers the way conversational topics are maintained throughout a conversation across different participants, or between conversations separated by time. Floor management is way in which conversations in different conversational *floors*, or sub-groups of speakers and audiences, can occur simultaneously without causing disruption. These dimensions provide structure for understanding conversations and therefore may be useful for decomposing work conversations. Also, as noted above, Suchman (1987) used communication-oriented methods in her research to analyze the interaction between the subjects and the photocopier help system. Heath and Luff (1993) also employed an analytic framework from conversational analysis, in order to describe both the contextual nature of the worker's behavior when using the video-mediated communication equipment, and the sequence of the types of interactions.

Example Applications

As described above, there are many methods which can be used to supplement the experimental and cognitive oriented methods of human-machine systems engineering to study work activities and interaction with technology. The need for this assessment has been recognized by researchers and designers in a number of diverse fields such as cognitive engineering (e.g. Woods, 1993), sociology (Button, 1993), computer supported cooperative work (Hughes, Randall, and Shapiro, 1992), human-computer interaction (e.g. Suchman, 1987) and software engineering, (Adler and Winograd, 1992; Rheinfrank, Hartman, and Wasserman, 1992). Research from these fields which have applied the qualitative and field study techniques described above will now be reviewed.

Some studies have focused on problems that occurred when new technology did not accommodate existing practices. For example, Button and Harper (1993) studied the implementation of a software system intended to support cost estimation, access to production specifications, and accounting for a manufacturing firm which produces foam forms in small batches to order; and found that, because the software was built to support the post-hoc accounting of production, rather than the actual work practices, the software actually hindered the timely production of orders. Similarly, in a case where software was introduced into a consulting firm to aid in cooperation, sharing of ideas, and access to information across projects and locations, Orlikowski (1992) found that the collaborative functionality of the software was not used as intended because, among other things, the organizational structure fostered and rewarded competition between consultants rather than cooperation.

In a different study, Heath and Luff (1993) examined the use of audio and video links between different offices and public spaces such as conference rooms, which was intended to enhance communication between workers in different physical locations. For example, workers might start a conversation upon "seeing" a colleague enter a room, or could observe if colleagues were busy before initiating a conversation, instead of disrupting them with a phone call. Heath and Luff found that in practice, the technology did not support collaborative work as well as intended because the media disrupted normal methods of communication. Waving or looking across the video link at colleagues did not gain their attention, and workers resorted to phone calls to initiate conversations across the monitors. Additionally, normal communication patterns such as hand gestures were cut off by the camera. In another ethnographic study, Nardi and Miller (1990) found that spreadsheets were often created and used collaboratively, rather than by individuals as assumed by spreadsheet designers.

Other studies which have used ethnographic techniques point to issues which are relevant in the study and analysis of the impact of new technology. For instance, in the medical domain, Koenig, (1988) used a combination of interviews and field observations to observe the introduction of a new treatment technology, which replaced patients' blood plasma with donated plasma. Among her findings, Koenig observed three things which have implications for other ethnographic studies of new technology. First, Koenig noticed a large change in the manner in which the new treatment technology was used from its initial testing phase to its use in routine treatment. The initial phase was marked by confusion, involvement of numerous personnel (doctors, nurses, representatives from the equipment manufacturer), and trips to other rooms to obtain extra equipment and documentation. Once the use was routine, however, this chaotic atmosphere changed into one or orderliness, where nurses prepared the equipment before the patient arrived, and a single nurse monitored the course of the treatment. It is important to note that while the routine treatments seemed straightforward overall, the nurses still had to respond to treatment difficulties (e.g. when poor blood flow increased the length of the treatment). However, these responses were not characterized by the confusion present in the initial phase. Therefore, making observations of a work setting, it is important not to assume that apparently routine behavior means that no problems are occurring; it may be that the individuals are just accustomed and have adapted to the difficulties. Another interesting observation was the way in which the roles of individuals changed with respect to the new technology. In the initial phase, doctors and nurses were both "hands-on" users of the equipment, trying to use it successfully. But, as the treatment became more routine, doctors ceased using the equipment and simply ordered the procedure; nurses were in charge of performing the treatment. This is similar to observations made in a manufacturing environment, where the initial users of a new piece of equipment were often the engineers and supervisors, who only later turn the equipment over to assembly personnel. Therefore, when studying the impact of a new or changed technology, it is important to observe for a long enough period so that the demographics of the user population observed (and the circumstances of use) are consistent with those of the true user population. Finally, Koenig points to the strong impetus to continue to use new technology which is being "tested," even if it is marginally useful. In this case, physicians' training tended to equate new technology with improved care. Compensation structures also favored high technology treatments over older or more preventative approaches. Therefore, organizational issues such as training and the financial investment in technology must be considered when evaluating its impact on the work place.

In response to the bulk of studies on technologically driven social changes which Barley (1988) claims have focused on economic (e.g. job loss, skill requirement changes), existential (e.g. alienation, lack of control over work) or structural (e.g. centralization or decentralization of work functions) issues, as well as the changing nature of tasks and skill, Barley proposed that new technology might also affect more "mundane" aspects of work and showed how ethnographic techniques could be used to identify such aspects, such as the temporal structure of daily events. The role of the assembly line in pacing work and railroad time tables in locomotive engineers schedules are examples of technology's impact on the temporal nature of the workplace.

Barley studied how new radiology technology (e.g. sonogram equipment, CAT scans) and the hospital departments created to use this equipment had a different temporal structure than traditional X-ray departments, due to a different match between equipment technicians' and radiologists' schedules. In the newer departments, the radiologists who interpreted the test results had fewer responsibilities outside that department and had work patterns which matched the technicians' schedules, which in turn were driven by patient need. In contrast, in the traditional departments radiologists were often interrupted for consultations and discussions with people around the hospital. In the second case, conflicts between radiologists and technicians occurred frequently, because technicians and patients were forced to wait for test interpretation. Barley found that people who inhabit "differently timed" social worlds are less likely to believe they have common goals and shared experiences and therefore are more in conflict.

Other studies have emphasized the role of artifacts in supporting shared information and communication. For instance, a study of British air traffic control centers (Bentley, Hughes, Randall, Rodden, Sawyer, Shapiro and Sommerville, 1992; Hughes, Randall, and Shapiro, 1992) which focused on the implicit and explicit communication between controllers and assistants, as well as the information and background knowledge shared by the individuals, found that displays of flight information could not be "user tailorable" to accommodate individual working strategies because they served as a shared source of information and therefore as an implicit means of communication. Suchman and Trigg (1991) also studied the use of artifacts as a shared source of information, among other things, in their observation of an airline ground operations room. In particular, they found that a paper grid showing flights into, out of, and transferring between gates during a set time period served as a common referent for individuals involved with such activities as transferring baggage or altering gate assignments, even if they did not have access to the sheet. They also noted the common means by which the sheets were annotated to show flights which spanned the time periods covered by the sheets, an activity which was not taken into to account in the design of the sheets but which was easily supported by the paper sheets. They emphasized the need for designers to understand how artifacts such as the grid sheets are used in practice, including their limitations and how they are modified by workers, if they are trying to augment or replace the existing technology.

Suchman's (1987) analysis of naive users interacting with a photocopier and its help system provides an illustrative example of the application of field studies and ethnomethodological methods to the study of human-computer interaction and design issues, as well as emphasizing the situated, rather than planned nature of action as discussed above. In addition, it attempted to expand the base of descriptions of human activity from which theories of human action can be drawn. Suchman combined an ethnomethodological approach with general theories of action, human computer interaction, and artifacts to address the problem of designing usable artifacts. The link between ethnomethodology and account of situated action is twofold: ethnomethodology both implicates and is implicated by a theory of situated action. By adopting an ethnomethodological viewpoint, Suchman found that the problem of understanding action is transformed from characterizing the plan to understanding the environmental context which shapes action. Also, Suchman feels that ethnomethodology, as a technique grounded in data rather than theory, is suited to the study of situated action, since it provides a description of the objects, artifacts, and actors that are a resource for and therefore necessary to the understanding of such action. In particular, ethnomethodology is suited to the study of human-computer interaction, since human-computer interaction can be thought of in the same terms as more general communication, which is an instance of situated action, for the following reasons.

Suchman makes the claim that the analysis of everyday communication can be used to understand human-machine interaction because of several crucial similarities between the two types of interaction. These similarities, which include the reactive rather than "batch-processed" nature of feedback from computers, the linguistic nature of communication, and the fact that the machine's reasoning mechanism is opaque to the user, result in a belief held by the user that the machine is responding and acting "intelligently," on a basis of shared understanding with the user. In a somewhat similar vein, Quintanilla (1987) describes human-machine interaction as a communication process between the machine operator and its designer, since machines or devices have intentions and demands which were incorporated by the designer. This communication will incorporate degrees of understanding and misunderstanding present in face to face communication, but appropriate feedback will be more difficult to provide. Finally, Suchman claims that communication, as an instance of action, can be characterized as situated because it is indexical in nature: the meaning of the language depends on the context. The shared meaning necessary for mutual intelligibility in communication is based not on a stable body of shared knowledge, but is achieved in each instance of communication. Garfinkel (1987) also describes the indexical nature of communication as a product of shared understanding, stating that many expressions cannot be understood through analysis without, among other things, understanding the purposes of speaker, the circumstances, the prior course of the conversation, and the nature of the relationship between speaker and listener.

In keeping with ethnographic methods, Suchman used videotape to capture naive users of a photocopier attempting a realistic task (making a two-sided copy of a bound document) with the help of the copier's help system. Her goal was to construct a characterization of the interaction between the users and the machine; however, to insure her characterization remained grounded in the data, she did not apply a pre-determined coding scheme in analysis. Instead, informed by general theories of communication including the need for shared understanding among participants, she analyzed the interaction in terms of the actions of the user and the machine, the design rationale behind the machine's actions, and the subset of these that were mutually available (e.g. which of the users activities could be sensed by the photocopier). Suchman found that the coherence of the user's actions was not available to the machine, due to both the limited number of the user's actions that the machine could sense and the fact that the systems designers' had programmed the system to respond to certain actions by mapping those actions onto a planning model of the user and trying to predict the user's goals. Another problem stemmed from the user's interpretation of the machine's actions. Since the users did not have access to the internal plan of the machine, they assumed that, for instance, any machine response to their action implied the appropriateness of that action. Thus, Suchman concluded that is was necessary for designers to correct the "asymmetry" of the mutually available actions by finding ways other than a planning model to compensate for the machine's lack of access to the user's intentions, by extending that access and by making the limitations of the machine's access more clear to users.

In summary, Suchman found support for her theories that actions are situated rather than planned through the study of a particular instance of action, users interacting with a photocopier. Through the use of ethnographic methods, appropriate due to their sensitivity to the entire context of action, and an analysis of the human-machine interaction informed by theories of communication, Suchman characterized the difficulties faced by the user due to the planning model of action embodied by the photocopier, and discussed design considerations.

Hutchins (19, 1990) describes analyses which can be considered ethnographic as well as ethnomethodological, since they provide accounts of action that are based in the context of a specific situation and are concerned with describing the actual social practices that allow groups to accomplish their work. In both cases, Hutchins provides a description of navigation which stresses the importance of developing theories of action from detailed observations, based on the viewpoint of those in the situation. In one study, Hutchins analyzed the observations of anthropologists who traveled with Polynesian navigators on canoes. In order to understand how these navigators successfully traveled between islands out of site of land, without navigational instruments, it was necessary to abandon Western theories of navigation. For example, previous researchers often misunderstood the navigators' system of expressing distance traveled in terms of the changing bearing of an unseen reference island as dividing the journey into segments corresponding to distance (the Western model) rather than (correctly) as segments of time.

In another example, Hutchins (1990) studied six crew members navigating a merchant ship close to land, in harbors. The task involved determining the present and predicted ship location based on the current heading and speed, and was completed every few minutes in restricted waters, due to the large inertia of the ship and the resultant time lag in response to control actions. To collect data, Hutchins observed crew actions, interactions, locations, communication patterns and methods, and the artifacts (e.g. pens, specialized navigation instruments, charts) that the crew used. These observations were used to construct a model of technology and cooperative work, and of the human interaction with technology. In this model, Hutchins considered members of the navigation team and the tools they used to be a "system of socially distributed cognition." The observations provided a view of technology as supporting a distribution of knowledge and information among the crew, instead of a view of technological systems as intelligent agents or amplifiers of human information processing abilities. This distribution of knowledge allowed crew members to communicate, to take over others work when needed, and to learn more complex jobs by observing the interaction between other team members who have more knowledge.

For example, observations of the work showed that the distributed nature of the navigation task across crew members allowed the members to work productively without coordinating the timing of their activities. In the process of taking, recording in a bearing log, and plotting bearings, the log served as an information buffer between the crew members taking bearings every few minutes from landmarks, and the plotter who worked more slowly. Hutchins also observed how the crew used procedures to coordinate their actives, and discovered that the coordinated activity was not directed in an encompassing, top-down way. Instead, coordination emerged from the interactions between a crew member, the technology used by that member, and the crew members that provide information to or receive information from that member. For instance, the bearing taker and plotter discuss the landmarks appropriate for the next "fix" (set of locating tasks), and the bearing takers wait to hear from the bearing recorder the time to site and mark the new bearing. Also, observation showed the dynamic nature of the allocation of task responsibilities, and indicated how that aided in the training of less experienced crew members. Unlike a normative description of responsibilities, Hutchins observed that crew members tended to contribute to all jobs when needed, according to their experience, so the system would function if one crew member was called away. Because crew members would help each other through open discussion, less experienced members could listen to, offer suggestions to, and learn about the jobs requiring more experience. This system functioned because crew members moved from less to more responsible positions, and therefore knew the functions of the jobs of the less experienced crew members.

In addition to theories of team coordination, Hutchins specified a theory of technological artifacts based on his observations of the navigational task. Instead of seeing artifacts as technological solutions, he theorized that successful artifacts make problems easy to solve by re-representing the information in the problem so that the solution is apparent. For instance, specialized nautical slide rules allow distance to be read directly given the speed and time, while experienced navigators realize that, due to the conversion factors between minutes and hours and yards and nautical miles, the number of 100 yards traveled in three minutes equals the nautical miles per hour (knots), and adjust the time between fixes accordingly. Artifacts also allow the representation of information to be changed as it is moved across different media until its ultimate transformation into a problem solution. For instance, in the navigation task, information about the ships position is transformed from a reading on the sighting tool, to a spoken bearing, to numbers in a bearing log, to lines of position on a chart which intersect to plainly show the position of the ship in space.

In summary, by focusing on observations of the work of navigating, and understanding that work from the point of view of the participants, Hutchins was able to describe how open communication between and shared responsibilities among crew members were essential to the navigation task. He concluded that introducing automation based on normative task allocation into this system might increase the risk of the system breaking down, due to a disruption in the open and dynamic nature of the crew coordination. Additionally, he theorized that the power of technological artifacts was not in their ability to augment human abilities, but instead to transform information into a form in which the solution is apparent.

Heath and Luff (1991) made similar observation to Hutchins (1990) and Suchman (1987) in their ethnographic study of workers and situated activities in a London Underground control room. Their study focused in part on using ethnomethodology and conversation analytic methods to describe the collaborative activity and communication between a controller who had day to day responsibility for running the railway, and an information assistant, who provided information about train times and delays to station managers and to passengers through a PA system. They observed the use of train location displays, radio systems, phones, and a paper timetable with cellophane overlays that could be marked. Heath and Luff found, among other things, that there was not explicit collaboration between the two workers, but the way they monitored each others work provided the information they needed to do their jobs. For example, by speaking loudly, coughing, and gesturing, the controller drew the attention of the information assistant to a phone call about a train delay, and the information assistant immediately moved to give that information to passengers. Also, by talking aloud to himself while making changes to the timetables, the controller made the new information available to the rest of the control room. Thus, just as Hutchins (1990) found that open communication between crew members was necessary for navigation, Heath and Luff found that in the rapidly changing environment of the control room, individuals relied on information that was made publicly available in order to run the trains rather than waiting for explicit communication. That is, not only did the collaborative work occur within a social context, but the collaboration required certain behavior and reasoning to be publicly available. The information provided by these activities was used systematically for the work of running the trains. Therefore, any technology designed to support such efforts must allow public access to changes and updates, such as those drawn on the time table.

Discussion

Many of the studies described used ethnographic and observational methods which provided extensive data. However, there is no magic in this approach: no design solutions are guaranteed. In fact, in the cases mentioned above (with the possible exception of Hutchins, 1990), the extensive data resulting from the analysis resulted in surprisingly few and general recommendations. This fact is noted by Bentley et al. (1992), who commented that ethnographic study does not result in design specifics but provides "pointers" to correct design decisions. Heath and Luff (1991) also claim that it is hard to draw conclusions regarding the design of technology from current studies of collaborative work. In other cases, there seems to be little link from the described data to the design recommendations (e.g. Hughes et al., 1992), and no methodologically prescribed way of incorporating observations into design recommendations. Also, it can be difficult to interpret the results of ethnographic studies due to the limited amount of data that is presented (Monk et. al, 1993). Monk et al. also make a good point in questioning whether or not the study of a particular group or situation is generalizable, or may actually be less representative than a laboratory study. Furthermore, it is not always clear from current examples what ethnographic methodologies can provide over more naturalistic methods of human-machine systems. For instance, as Suchman (1987) discusses, an ethnographic approach to the study of communication reveals that the development of shared understanding in a conversation, required for successful communication, depends on the interaction between the listener and the speaker. In particular, the speaker must notice the listener's cues (expressions, verbalizations, etc.) and adjust accordingly. This important aspect of communication was not apparent from other studies of conversation which tried to understand language in terms of the speaker's plans, independent of the listener and the intricacies of natural communication, However, Button and Harper's (1993) recommendation that designers should understand the work that is to be supported by the new technology is a widely stated and understood goal of cognitive work analysis (e.g. see Roth and Woods, 1988). It seems all that can be asserted is that the researchers conducting ethnographic studies believe they are capturing some aspects of the situation relevant to the design and implementation of new technology which they would not have otherwise observed.

Additionally, when considering the design of technology for an existing workplace, the goal of preserving and accommodation work practices must be examined: it is necessary to consider at what level of practice preservation is required, and if that preservation is possible and even desirable. For instance, consider the air traffic control example described by Bentley et al. They claim that, in order for controllers to maintain an accurate sense of the air traffic in their sector, it is necessary to preserve the manual activity of ordering the paper flight information strips. Thus, when computerizing the flight information, controllers must still be able to explicitly order strips rather than having them automatically arranged. In one sense, the work activity - ordering of strips - is preserved, but in another sense, at the level of actual physical interaction, it is not - controllers are manipulating some computer input device rather than the actual paper strips. In the language of the abstraction hierarchy (Rasmussen, 1985), which is used to describe systems at different levels of functional abstraction, the physical form level of the system, which includes the physical components controllers interact with, is not preserved. From some of the studies reviewed above, it appears that the appropriate level at which to preserve practice is taken to be the level that describes the form and content of the communication between people. Bentley et al. discuss the tension present during design between software engineers, who want specific information about characteristics of the current manual system which should be preserved, changed, or disregarded during automation, and the sociologists, who find it difficult to separate the work practices from the manual tools being used to make such judgments. In fact, some of this tension can be seen as a negotiation between the software engineers and the sociologists studying the environment about the appropriate level of abstraction at which extant work practices should be preserved and accommodated.

Application to the design of retail technologies

Although there are significant difficulties predicting a priori the types of design recommendations that can be drawn from the data, these methods may still be useful in the design and evaluation of retail technologies, for several reasons. First, it would add new dimensions to the current analysis process, which focuses on the overt behavior of individual cashiers. Studying the entire work situation, including organizational structure, communication between employees and customers, and the flow and use of information in the workplace can provide design relevant information in addition to the current time and motion information. Additionally, the technology used affects not only the work practices of employees, but also the situational practices of sales, including actions of the customer and interactions among the customer, employees, and technology. Expected practices and social norms from the point of the customer as well as the employees must be accommodated at some level for the introduction of technology to be successful.

There are several possible ways this type of analysis could be applied. First, it could be used to study a current implementation of technology in one or several locations, in order to identify difficulties with its use in terms of the communication or organization factors discussed above, which would then result in design recommendations for new technologies. Similarly, the methodologies could be used during the design phase to identify important characteristics of the workplace and the interactions that occur there, that would need to be supported with proposed technology. A more theoretical study would use these observations before a technology was implemented to make predictions about the impact of the technology on the workplace, and compare these predictions to data obtained during and after the implementation of the technology. This type of study could be conducted at either one site over an extended period of time, or at several sites which are at different stages of technology implementation. Additionally, laboratory experiments testing the more general design principles of theories of interaction derived from the observational data could be performed, using either design prototypes or simulated systems. In all cases, theories to help organize, interpret, and derive design recommendations from the data could be drawn from areas such as computer supported cooperative work, situated action, distributed cognition, communication theory, and cognitive psychology.

The results of the field study and subsequent analysis should include three components. First, the study should provide specific design recommendations based on existing work practices and organizational structure which will facilitate the design of a product which can be incorporated and used successfully. Second, more abstract design issues and guidelines which will be useful in the development of future studies and products will be provided. Finally, the study should demonstrate how ethnographic methods can be adapted and used to answer engineering design questions, as well as questions of a more descriptive nature.

References

Adler, P. S. (1992). Introduction. In P. S. Adler, (Ed.) *Technology and the Future of work*. New York: Oxford University Press. 3 - 14.

Adler, P. S. and Winograd, T. A. (1992). The usability challenge. In P. S. Adler and T. A. Winograd, (Eds.) *Usability: Turning tools into technologies*. New York: Oxford University Press, 3 - 14.

Attewell, P. (1992). Skill and occupational changes in U.S. manufacturing. In P. S. Adler, (Ed.) *Technology and the Future of work*. New York: Oxford University Press. 46 - 88.

Barley, S. R. (1988). On technology, time and social order: technically induced change in the temporal organization of radiological work. In F. A. Dubinskas, (Ed.) *Making time: ethnographies of high-technology organizations*. Philadelphia, PA: Temple University Press. 123 - 169.

Bentley, R., Hughes, J. A., Randall, D. Rodden, T., Sawyer, P. Shapiro, D. and Sommerville, I. (1992). Ethnographically-informed systems design for air traffic control. *Computer Supported Cooperative Work Proceedings, 1992*. New York: Association for Computing Machinery. 123 - 129.

Button, G. (1993). The curious case of the vanishing technology. In G. Button (ed.) *Technology in working order: Studies of work, interaction, and technology*. New York: Routledge, 10 - 30.

Button, G. and Harper, R. H. R. (1993). Taking the organisation into accounts. In G. Button (ed.) *Technology in working order: Studies of work, interaction, and technology*. New York: Routledge, 98 - 110.

Erikson, F. (1982). Money tree, lasagna bush, salt and pepper: Social construction of topical cohesion in a conversation among Italian-Americans. *Analyzing discourse: text and talk, Georgetown University Roundtable on Languages and Linguistics*. Washington D.C.: Georgetown University Press.

Garfinkel, H. (1967). *Studies in Ethnomethodology*. Englewood Cliffs, NJ: Prentice Hall.

Hartland, J. (1993). The use of 'intelligent' machines for electrocardiograph interpretation. In G. Button (ed.) *Technology in working order: Studies of work, interaction, and technology*. New York: Routledge, 55 - 80.

Heath, C. and Luff, P. (1991). Collaborative Activity and technological design: Task coordination in London Underground control rooms. In L. Bannon, M. Robinson, and K. Schmidt (Eds.) Proceedings of the second European conference on computer-supported cooperative work. Boston: Kluwer Academic Publishers. 65 - 80.

Heath, C. and Luff, P. (1993). Disembodied Contact: Interactional asymmetries in video-mediated communication. In G. Button (ed.) *Technology in working order: Studies of work, interaction, and technology.* New York: Routledge, 35 - 54.

Hirschorn, L. and Mokray, J. (1992). Automation and Competency requirements in manufacturing: A case study. In P. S. Adler, (Ed.) *Technology and the Future of work.* New York: Oxford University Press. 15 - 45.

Hughes, J. A. Randall, D. and Shapiro, D. (1992). Faltering from Ethnography to Design. *Computer Supported Cooperative Work Proceedings, 1992.* New York: Association for Computing Machinery. 115 - 122.

Hutchins, E. (). In Gentner and Stevens (Eds.), *Mental Models.*

Hutchins, E. (1990). The technology of team navigation. In J. Galegher, R. E. Kraut, and C. Egido, (Eds.) *Intellectual teamwork: Social and technological foundations of cooperative work.* Hillsdale, NJ: Lawrence Erlbaum. 191 - 220.

Jordan, B. and Henderson, (in press). Interaction analysis: Foundation and practice. Unpublished Manuscript. (???)

Kern H. and Schumann M. (1992). New Concepts of production and the emergence of the systems controller. In P. S. Adler, (Ed.) *Technology and the Future of work.* New York: Oxford University Press. 111 - 148.

Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. A. Klein, J. Orasanu, R. Calderwood, and C. E. Zsambok, (Eds.) *Decision making in action: Models and methods.* Norwood, NJ: Ablex Publishing. 138 - 148.

Koenig, B. A. (1988). The technological imperative in medical practice: the social construction of a "routine" treatment. In M. Lock and D. R. Gordon (Eds.), *Biomedicine Examined.* Norwood, MA: Kluwer Academic Publishers. 465 - 496.

Livingston, E. (1987). *Making sense of ethnomethodology.* London, Routledge and Kegan Paul.

Luff, P. and Heath, C. (1993). System use and social organization: observations on human-computer interaction in an architectural practice. In G. Button (ed.) *Technology in working order: Studies of work, interaction, and technology.* New York: Routledge, 184 - 210.

Minneman, S. L. (1991). *The social construction of a technical reality: Empirical studies of group engineering design practice.* Xerox PARC SSL-91-22. Palo Alto, CA: Xerox PARC.

Monk, A., Nardi, B., Gilbert, N. Mantei, M. and McCarthy, J. (1993) Mixing oil and water? Ethnography versus experimental psychology in the study of computer-mediated communication.

Panel discussion. In *Proceedings of INTERCHI 1993 (Amsterdam, The Netherlands, April 24 - 29, 1993).* New York: Association for Computing Machinery, 3 - 6.

Montmollin, M. de (1991). Analysis and models of operators' activities in complex natural life environments. In J. Rasmussen and H. B. Anderson (Eds.) *Research directions in cognitive science: European perspectives. Vol. 3, Human-computer interaction.* Lawrence Erlbaum Associates, Lt.: East Sussex UK. 95 - 112.

Orlikowski, W. J. (1992). Learning from Notes: Organizational issues in groupware implementation. *Computer Supported Cooperative Work Proceedings, 1992.* New York: Association for Computing Machinery. 326 - 369.

Quintanilla, S. A. R. (1987). New Technologies and Human Error: Social and Organizational Factors. In J. Rasmussen, K. Duncan, and J. LePlat, (Eds.) *New Technology and Human Error.* Chichester: Wiley and Sons, 125 - 128.

Rasmussen, J. (1985). The role of hierarchical knowledge representation in decisionmaking and system management. *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-15, 2, 234 - 243.

Rasmussen, J. (1986). A framework for cognitive task analysis in systems design. In E. Hollnagel et al. (Eds). *Intelligent decision support in process environments.* Heidelburg: Springer Verlag. 175 - 196.

Reason, J. (1987). Collective planning and its failures. In J. Rasmussen, K. Duncan, and J. LePlat (Eds.) *New Technology and Human Error.* Wiley and Sons: Chichester, 121 - 124.

Rheinfrank, J. J., Hartman, W. R. and Wasserman, A. (1992). Design for usability: Crafting a strategy for the design of a new generation of Xerox copiers. In P. S. Adler and T. A. Winograd, (Eds.) *Usability: Turning tools into technologies.* New York: Oxford University Press, 15 - 40.

Roth, E. M. and Woods, D. D. (1988). Aiding human performance I: Cognitive analysis. *Le Travail humain*, 51, 1, 39 - 64.

Strauss, A. and Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park: Sage Publications.

Suchman, L. A. (1987). *Plans and situated action: the problem of human-machine communication.* Cambridge: Cambridge University Press.

Suchman, L. and Trigg, R. H. (1991). Understanding practice: video as a medium for reflection and design. In J. Greenbaum and M. Kyng (Eds.) *Design at work: cooperative design of computer systems.* Hillsdale, NJ: Lawrence Erlbaum. 65 - 89.

Traweek, S. Discovering machines: nature in the age of its mechanical reproduction. In F. A. Dubinskas, (Ed.) *Making time: ethnographies of high-technology organizations*. Philadelphia, PA: Temple University Press. 39 - 91.

Watts, J. C. (1994). *A Cognitive Analysis of Navigation in the Computer Medium.* Cognitive Systems Engineering Laboratory Report 1994-02. Ohio State University.

Woods, D. D. (1993). Process tracing methods for the study of cognition outside of the experimental psychology laboratory. In G. A. Klein, J. Orasanu, R. Calderwood, and C. E. Zsambok, (Eds.) *Decision making in action: Models and methods*. Norwood, NJ: Ablex Publishing. 228 - 251.